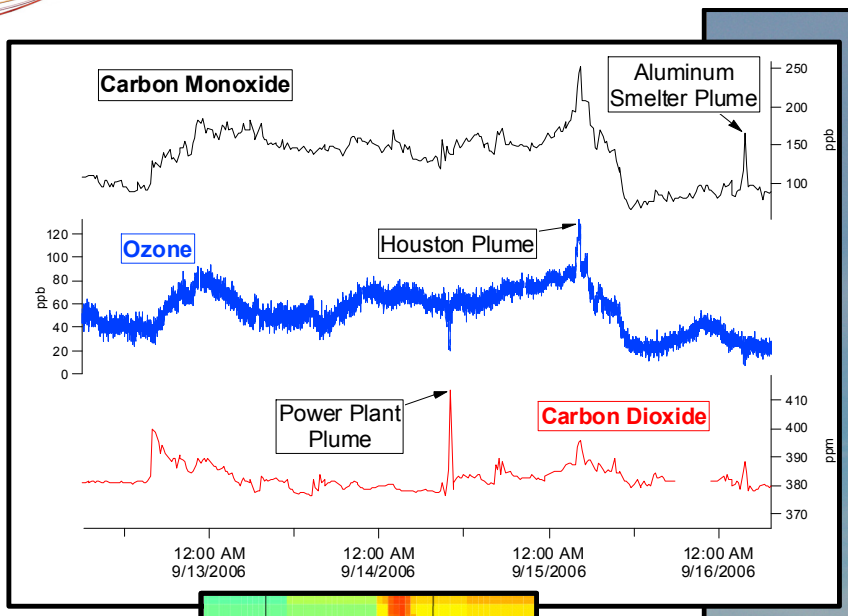
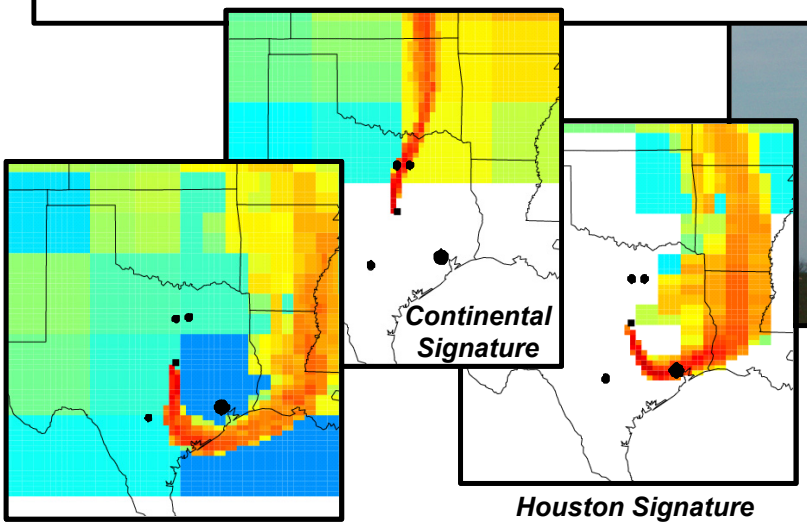
Earth System Research Laboratory

Global Monitoring Annual Conference

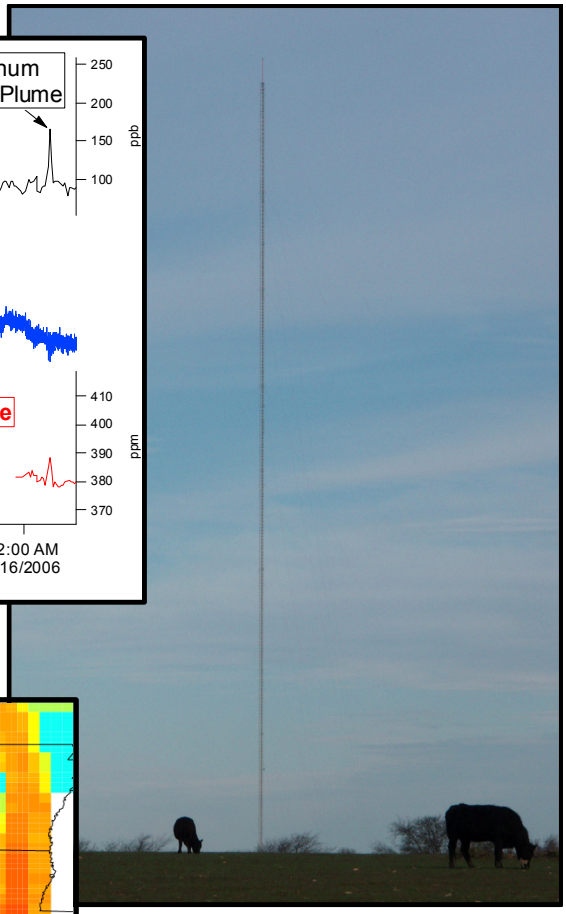
A B S T R A C T S





Clean Marine Signature

Houston Signature



May 14th-15th, 2008
Boulder, Colorado

ESRL's Global Monitoring Division instrumented three new tall towers in 2007 to increase the network to six sites total. Shown above right is the 650m tall KWKT-TV transmitter tower near Moody, Texas used to measure carbon dioxide, carbon monoxide, ozone and a suite of meteorological parameters. The WKT tower samples polluted and clean air, as illustrated here for several days during September 2006. Pollution signatures from urban centers as well as individual industrial sources stand out as distinctive features in the measurement record. The sampling footprints at bottom left were calculated using the Stochastic Lagrangian Transport (STILT) particle dispersion model.

Office of Oceanic and Atmospheric Research
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

2008 NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE

David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305
May 14 and May 15, 2008

Wednesday, May 14th, 2008 AGENDA

(Only presenter's name is given; see abstract for complete author listing.)

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A New Look at Anthropogenic Atmospheric Carbon Dioxide

D.J. Hofmann[1] and P.P. Tans[2]

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When seasonal variations are removed, and the pre-industrial level of carbon dioxide (280 ppm) is subtracted, the atmospheric carbon dioxide level as measured at Mauna Loa Observatory and for the global network closely follow an exponential function with a doubling time of about 30 years (see black dashed line in the figure). Even during the 1970's, when fossil fuel emissions dropped sharply in response to the "oil crisis" of 1973, the anthropogenic atmospheric carbon dioxide level continued increasing exponentially at Mauna Loa. Since the growth rate (time derivative) of an exponential has the same characteristic lifetime as the function itself, the carbon dioxide growth rate is also doubling every 30 years. This explains the observation that for linear growth rates, carbon dioxide increased from less than 1 ppm per year to more than 2 ppm per year in the past 40 years. It is argued that this is expected since world population and Gross Domestic Product are increasing exponentially with similar rates of growth.

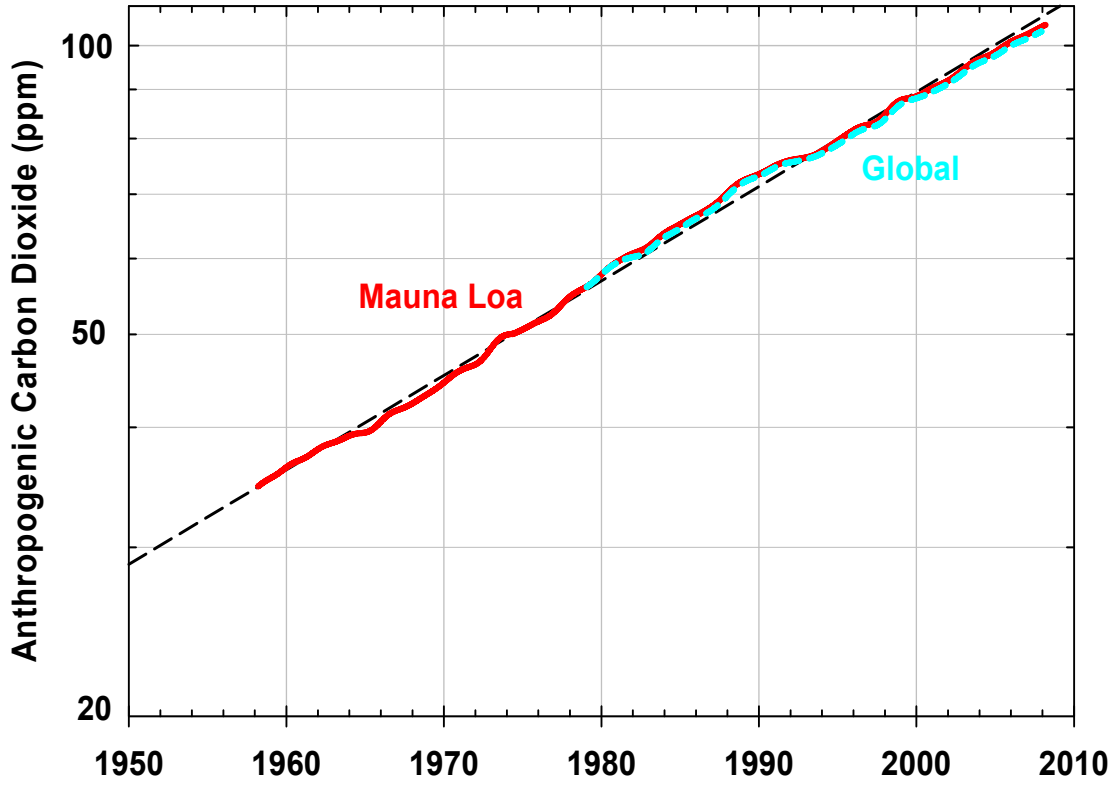

Figure 1. Deseasonalized, anthropogenic, atmospheric carbon dioxide measured at Mauna Loa Observatory (red curve) and the global average (cyan dashed curve) plotted versus time on a semi-logarithmic scale. The straight black dashed line is an exponential relation with a doubling time of about 30 years (about 2.3% per year).

How High Could CO_2 Go?

P.P. Tans

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The growth of carbon dioxide emissions from the burning of coal, oil, and natural gas has been more or less exponential since the start of the 20th century, with an average rate of increase of 2.7% per year. At this point the observed increase of atmospheric CO_2 has been entirely due to our own activities. Substantial further increases depend mostly on three factors: the total earth resources of coal and hydrocarbons, the pace we can achieve in de-carbonizing our energy system, and the response of the natural system to climate change itself. Climate change as an unintended byproduct of our activities poses a major challenge to our economic system, especially to our expectations of growth, to our long-term goals, and measures of success.

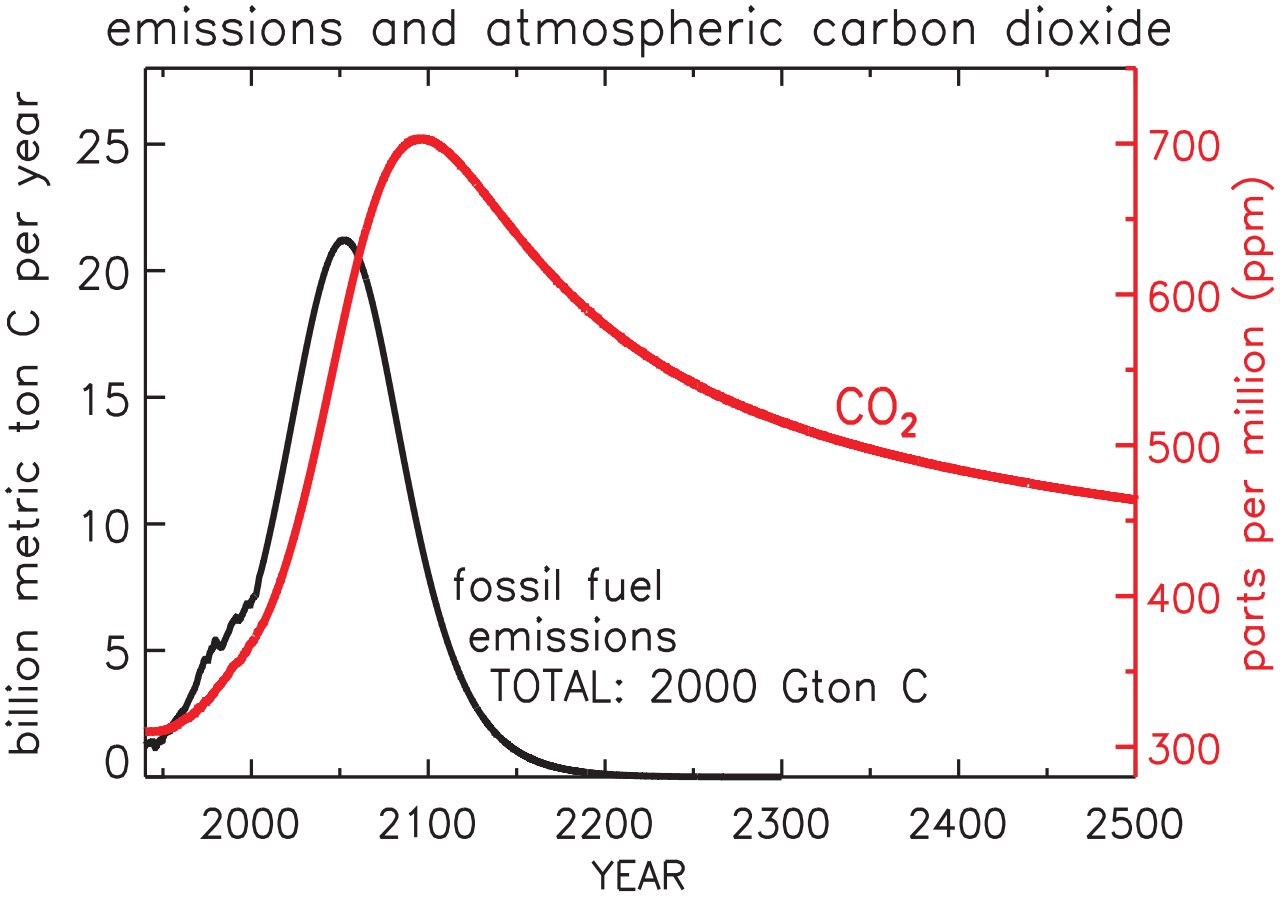

Figure 1. Black curve: Emissions from the burning of fossil fuels according to a logistics function, if all global reserves are consumed. Growth is initially exponential, slowing after the largest and most easily accessible deposits are consumed, peaking as the halfway point is reached, and then steadily declining until exhaustion. Emissions through 2006 are historical. The projected growth rate in 2007-2013 was chosen to equal the 2000-2006 pace. Red curve: The atmospheric CO_2 level that would result from such an emissions trajectory.

Continued Permafrost Warming in Northern Alaska, 2007 Update

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USGS maintains a permafrost monitoring network on federal lands in northern Alaska as part of the Global Terrestrial Network for Permafrost (GTN-P). This network consists of two arrays: 1) An array of 15 automated meteorological/active-layer stations, and 2) an array of 20 deep boreholes, the majority of which are located on the Arctic Coastal Plain (a few are located in the foothills of the Brooks Range). Temperature measurements are made in the deep borehole array every 5 years to monitor the thermal state of permafrost from the surface down to 125+ meters.

During the summer of 2007, permafrost temperatures were obtained from the portion of the borehole array located on the Arctic Coastal Plain as part of an international effort to obtain a global snapshot of the thermal state of permafrost during the International Polar Year. Previous measurements made in the USGS/GTN-P borehole array had shown little trend in permafrost temperatures during the 1980s, followed by a ~3 K warming between 1989 and 2002-03. The 2007 measurements show that shallow permafrost temperatures have continued to warm since 2002-03. The magnitude of the warming ranges from 0.0 to 1.0 K (mean = 0.4 K), depending on local site conditions. The total average permafrost warming in this region since 1989 is now ~ 3.5 K.

Data from the co-located USGS/GTN-P meteorological array show that the 2002-03 borehole measurements coincided with a peak in mean-annual air temperatures on the Arctic Coastal Plain in Alaska. Mean-annual air temperatures cooled substantially during 2004, but have been rising since and are now warmer than those experienced during 2002-03.

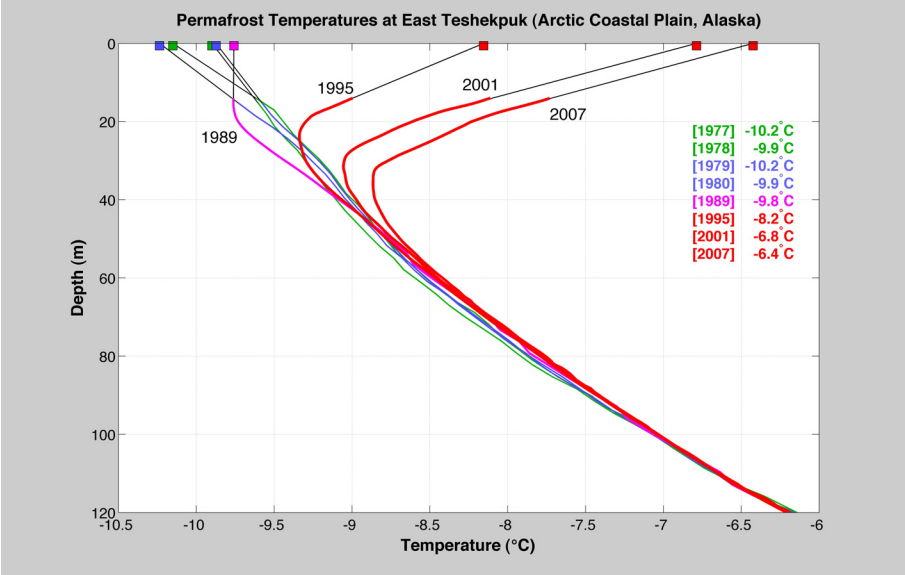

Figure 1. Permafrost temperatures measured in the East Teshekpuk borehole on the Arctic Coastal Plain in Alaska since 1977. Also shown are the extrapolated mean-annual surface temperatures which have increased about 3.6 K at this site since the late 1970s. East Teshekpuk is one of 20 deep boreholes currently monitored by the U.S. Geological Survey in Arctic Alaska.

System S

O. Verscheure

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As the amount of data available to enterprises and other organizations dramatically increases, more and more organizations are looking to turn this data into actionable information and knowledge. IBM has developed the System S platform as a Research initiative, to address these requirements by enabling efficient extraction of knowledge and information from potentially enormous volumes and varieties of continuous data streams. System S is designed to scale from systems that acquire, analyze, interpret, and organize continuous streams on a single processing node, to high performance clusters of hundreds of processing nodes. System S provides an execution platform and services for user-developed stream processing applications. It supports the composition of new applications in the form of stream processing data flow graphs that can be created on the fly, mapped to a variety of hardware configurations, and adapted as requests come and go, and relative priorities shift. This allows for adaptive, hypothesis-based analysis of data, simultaneous evaluation of alternate analysis models, and discovery of new information and intelligence from data streams. Stream processing applications can be found in areas as diverse as radio-astronomy, manufacturing, and energy-trading. In this presentation, we will describe the System S programming paradigm, its capabilities, as well as a few applications that researchers at IBM T.J. Watson Research Center are engaged in.

The System S architecture represents a significant change in computing system organization and capability. Users compose stream-processing applications as a stream-processing dataflow graph, as shown in the figure. The System S runtime environment accepts these specifications, determines how it might reorganize itself in order to best meet the requirements of newly submitted and already executing specifications, and automatically effects the changes required. The runtime continually monitors and adapts to the state and utilization of its computing resources, as well as the information needs expressed by the users, and availability of data to meet those needs.

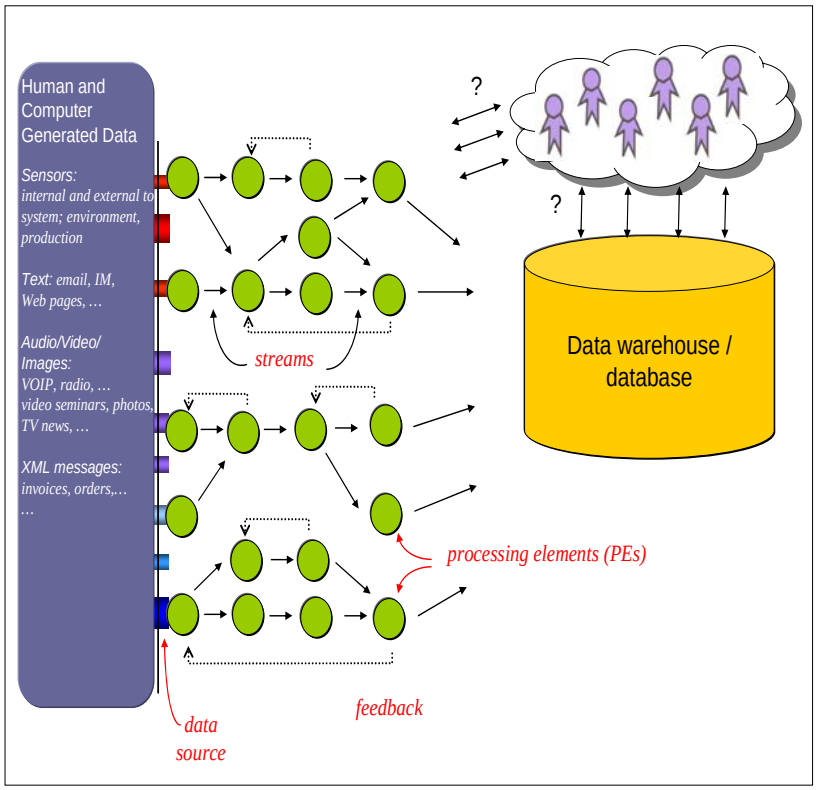

Figure 1. System S architecture.

A Lagrangian Particle Dispersion Model Approach for Evaluating CarbonTracker

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Lagrangian particle dispersion models (LPDMs) are gaining popularity for analysis and inverse-modeling of carbon dioxide measurements obtained from tall towers and aircraft. LPDMs suffer minimal numerical diffusion and are thus well-suited for studying highly variable data obtained in the vicinity of strong sources and sinks. Here, we explore the potential to use an LPDM as a pseudo-adjoint for the CarbonTracker CO_2 data assimilation system. For this work, we have chosen the Stochastic Time-Inverted Lagrangian Transport (STILT) model driven by a customized, high-resolution version of the Weather Research and Forecasting (WRF) model. Two years of meteorological driver data, 2004 and 2006, are available with 1.6km resolution in the vicinity of three NOAA Earth System Research Laboratory tall tower sites and 10 km resolution over much of the continental US. Sampling footprints from the LPDM can be used to critically examine various aspects of the CarbonTracker framework. For example, LPDM footprints can be convolved with CarbonTracker fluxes to isolate differences in simulated transport between STILT-WRF and the TM5 model used for CarbonTracker. Footprints can also be used to quantitatively project CarbonTracker residuals onto ecosystem maps or onto gridded meteorological driver data such as temperature, short-wave radiation and soil moisture. High-resolution STILT-WRF simulations can be used to develop strategies for minimizing model representation errors during CarbonTracker's assimilation step, when differences between observed and simulated CO_2 are used to adjust fluxes.

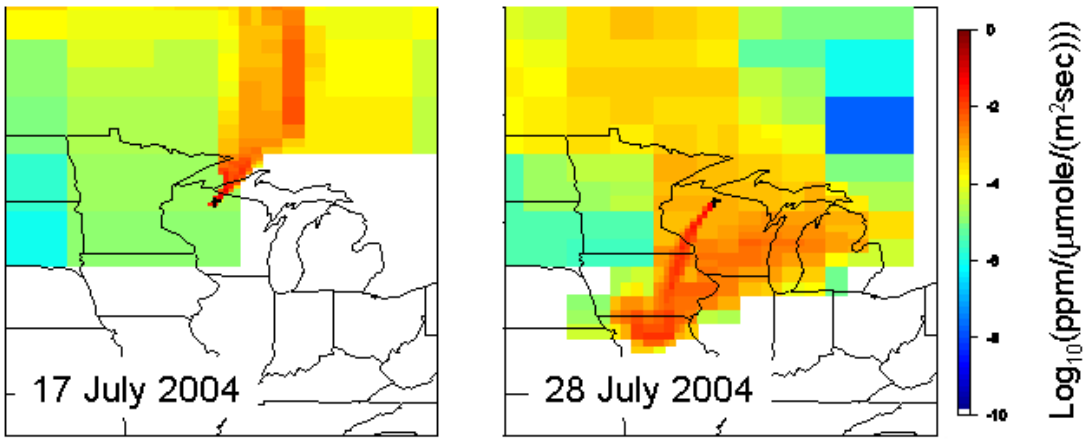

Figure 1. Typical mid-afternoon STILT footprints for the Park Falls, WI (LEF) tall tower site. The color scale is logarithmic and represents sensitivity to surface flux.

Total Column Carbon Observing Network: Variability in Total Column CO_2 and CO

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The Total Column Carbon Observing Network (TCCON) is a growing network of ground-based high resolution Fourier Transform Spectrometers optimized to observe gases, including CO_2, CO, CH_4, N_2O, HF, H_2O, and O_2, with transitions in the near-infrared (details at tccon.caltech.edu). In this presentation we focus on two sources of variability to the total column CO_2 record: synoptic-scale weather and biomass burning. First, we present 3.5 years of total column carbon dioxide data from the first dedicated TCCON site at Park Falls, Wisconsin. This represents the longest time series of measured total column CO_2 and provides new information on the variability of mid-latitude CO_2. We find that synoptic scale variability dominates the CO_2 column variability, particularly during summer. We regress CO_2 anomaly against potential temperature anomaly, a dynamical signal, to find that synoptic activity contributes +/- 2 ppm to the total column signal on top of the seasonal cycle. The observed range of synoptic-scale variability is not captured in transport models such as MATCH, or reanalysis products such as CarbonTracker. Second, we demonstrate the influence of burning on CO_2 observations at three sites in the TCCON network: Park Falls, Wisconsin; Darwin, Australia; and Pasadena, California. Simultaneous observations of total column CO enable us to better understand the influence of biomass burning on CO_2 variability.

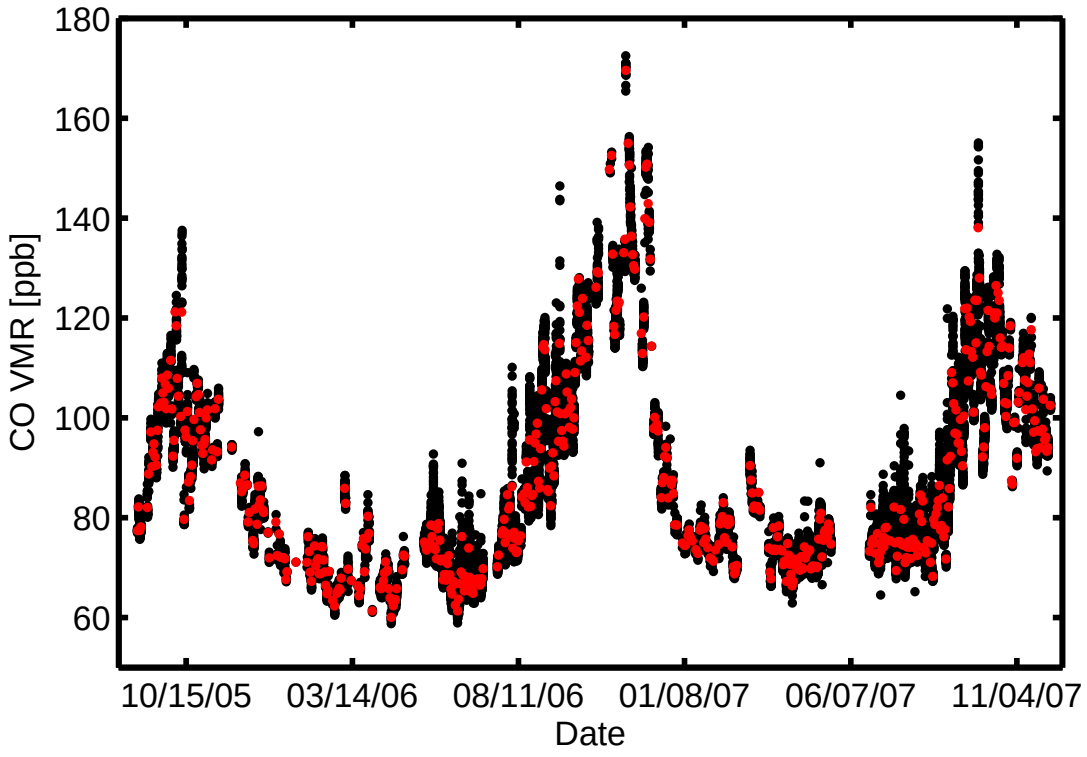

Figure 1. Total column carbon monoxide retrieved from ground-based FTS spectra obtained at Darwin, Australia.

Bridging Carbon Cycling and Air Quality Studies Using Atmospheric $^{14}CO_2$

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$\Delta^{14}C$, the ratio of radiocarbon to total carbon, is a theoretically ideal tracer for recently added fossil fuel CO_2, because fossil fuel is ^{14}C-free. In contrast, all other carbon reservoirs that exchange CO_2 with the atmosphere, like the terrestrial biosphere and the oceans, are relatively rich in ^{14}C. Since 2004, NOAA ESRL and the University of Colorado Institute of Arctic and Alpine Research (INSTAAR) Radiocarbon Laboratory have worked together to make high precision (< 2 ‰) $\Delta^{14}C$ measurements. Our two sites in the eastern USA, Portsmouth, NH (NHA) and Cape May, NJ (CMA) exhibit large CO_2 signals from anthropogenic and biogenic fluxes. Using $\Delta^{14}CO_2$, however, we are able to quantitatively partition the boundary layer CO_2 signal into biogenic and fossil fuel components. Once separated, these signals are independently useful. The biological signal can be used directly to infer the uptake and release of carbon by the biosphere, and the fossil signal can constrain anthropogenic emissions of CO_2, without the use of inventories, which can never be as recent as the measurements. Furthermore, as we will show, the derived fossil fuel CO_2 signal is closely related to boundary layer enhancements of many air quality tracers like CO, SF_6, CFC-replacement compounds, and solvents like perchloroethylene and dichloromethane. These relationships can exist for total CO_2, but we will show that they are biased because of the biospheric contribution. Finally, having established a relationship between fossil fuel CO_2 and air quality tracers, we will estimate regional scale (east coast) emissions of the air quality tracers by scaling the measured fossil-CO_2:tracer emission ratios to the well-known U.S. fossil fuel CO_2 inventory. As more $^{14}CO_2$ measurements are made, we will improve not only our understanding of CO_2 sources and sinks, but potentially emissions for a wide variety of other gases.

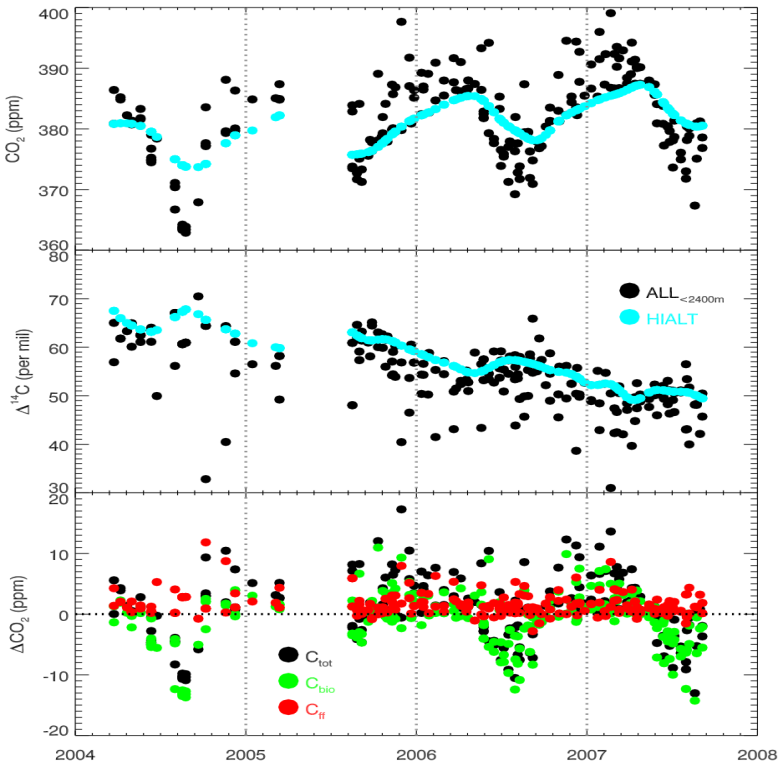

Figure 1. Fossil and biospheric CO_2 signals for boundary layer (PBL) aircraft air samples above Portsmouth, NH (NHA) and Cape May, NJ. Top and middle panels show PBL (black) and a composite free troposphere (blue) reference time series for CO_2 and $\Delta^{14}CO_2$, respectively. Note that whereas for CO_2, the PBL values are both above and below the reference, for $\Delta^{14}C$, the values are generally below the reference, showing the influence of fossil fuel emissions. The bottom panel shows the PBL-reference time series for CO_2 (black; C_{tot}) and the $\Delta^{14}C$-derived values of the biological (green; C_{bio}) and fossil (red; C_{ff}) components. We see that even in winter, there are significant contributions from both biospheric and fossil fuel CO_2 to the total. In summer, we also see that C_{tot} underestimates the full extent of the photosynthetic drawdown of CO_2 shown by C_{bio}.

Quantifying Regional GHG Emissions from Atmospheric Measurements: HFC-134a at Trinidad Head

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Top-down approaches to emissions analysis provide a method of assessing bottom-up emission inventories and thus can be used to assess and validate reported inventories. At the AGAGE (Advanced Global Atmospheric Gases Experiment) measurement station at Trinidad Head on the Northern California coast (41°N, 124°W) *Medusa* GC/MS, GC/ECD and GC/FID instrumentation measures a wide range of trace gases in ambient air at high time resolution and high precision. Here, the western US emissions of the greenhouse gas (GHG) HFC-134a are estimated using Trinidad Head *Medusa* HFC-134a measurements, an atmospheric dispersion model (NAME), and an inversion methodology. NAME (Numerical Atmospheric dispersion Modelling Environment) is a Lagrangian atmospheric dispersion model that uses 3D meteorology from the UK Met Office numerical weather prediction model. Mid-latitude Northern Hemisphere baseline concentrations of HFC-134a are determined using NAME and statistical post-processing of the Trinidad Head observations, and this baseline is used to generate a time series of "polluted" (above baseline) observations. In this application NAME is run backwards in time for ten days for each 3 hour interval in 2006 releasing thousands of model particles at the observing site. A map is then produced estimating all of the surface (0-100m) contributions within ten days of travel arriving at the observing station during each interval. The resulting matrix describes the dilution in concentration that occurs from a unit release from each grid as it travels to the measurement site.

Inversion modeling with an iterative simulated-annealing algorithm is then carried out to generate an emission estimate that provides the best statistical match between the modeled time series and the observations. Uncertainty in the emission estimates is captured by starting from a randomly generated emission map, randomly perturbing the observations by a noise factor, and solving the inversion multiple times using different skill score (cost) functions. The model results indicate that the combined emissions from the five western states of the US (California, Washington, Oregon, Nevada, and Idaho) for 2006 fall in the range 3.7 – 10 kt. If one assumes that the emissions of HFC-134a are relatively constant per head of population within the US, the emissions of HFC-134a for the US for 2006 are estimated to be 43kt (uncertainty range: 22-60 kt). The estimated emission distribution picks out most of the significant populated areas and estimates very low emissions from the ocean areas. This is consistent with the understanding that HFC-134a is emitted broadly in line with population as it is widely used as a refrigerant, e.g. in car air conditioners. The method can be extended to utilize observations from multiple stations. Using more data from different geographical locations significantly improves the ability of the inversion process to estimate both the magnitude and the distribution of the emissions. Accordingly, a network of several well-located stations could be used to quantify regional emissions of all measured GHGs and their changes over time within a regulatory framework such as California's new Assembly Bill 32 legislation.

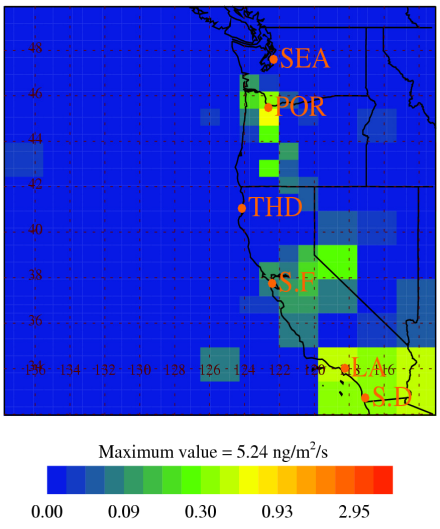

Figure 1. Estimated western US emission of HFC-134a for 2006. Trinidad Head (THD) and major western cities are shown.

Thirty Years of Global Atmospheric Methane and Ethane Monitoring: What Can Ethane Teach us About Methane?

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Methane (CH_4) is the second largest human contribution to the positive radiative forcing of the atmosphere, after carbon dioxide. Methane is also the main cause of increasing levels of tropospheric ozone, which is the third most important anthropogenic greenhouse gas. UC-Irvine has directly monitored global trace gas mixing ratios for 30 years, since 1978. Every three months ~80 whole air samples are collected in the remote Pacific Basin (71°N-46°S) and analyzed by gas chromatography for many dozens of compounds including methane, ethane, ethyne, propane, *i*-butane, *n*-butane, CFC-11, CFC-12, CFC-113, CCl_4, CH_3CCl_3, $CHCl_3$, C_2Cl_4, H-1211, CH_3Br, methyl nitrate, ethyl nitrate, *i*-propyl nitrate, and carbonyl sulfide.

This diverse suite of compounds has been used to refine our understanding of the factors that control methane's long-term and short-term growth rate variations. In the long-term, methane's annual growth rate has slowed from 15.2 (± 1.0) to 18.9 (± 1.0) ppbv yr^{-1} in the early-to-mid 1980s to –3.8 (± 1.2) to 6.6 (± 0.9) ppbv yr^{-1} since 2000. Whereas CH_4 levels have continued to slowly increase in the latitudinal band from 22-30°N, we have not seen evidence for any new CH_4 sources at northern latitudes (>60°N) in response to global warming, for example permafrost, thaw lakes or wetlands. In the short-term, CH_4 has shown positive growth rate anomalies every 3½-4½ years since 1991, the fifth and most recent of which peaked at 6.6 (± 0.9) ppbv yr^{-1} in 2007. Because CH_4, ethane and C_2Cl_4 are all OH-controlled species—but only CH_4 and ethane have common anthropogenic sources (fossil fuel and biomass burning)—CH_4, ethane and C_2Cl_4 are a powerful combination to help us determine which source and sink variations are consistent with the observed trends. For example, coincident CH_4 and ethane variations that are not matched by C_2Cl_4 point to fossil fuel and/or biomass burning influences, and help to constrain the influence of changing wetlands emissions in both the long- and short-term. These and other results will be presented and discussed at the meeting.

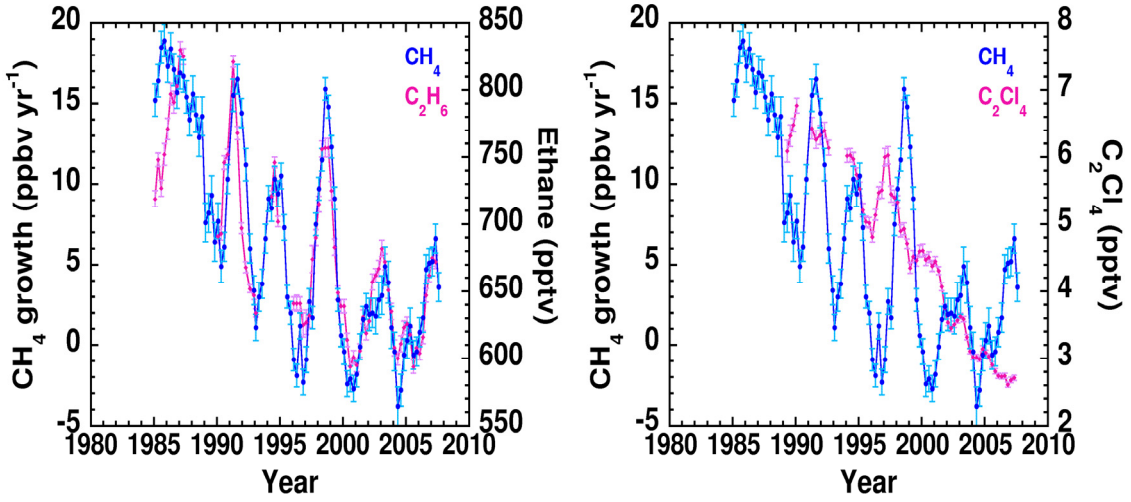

Figure 1. Global CH_4 growth rates (blue), global ethane mixing ratios (pink, left), and global C_2Cl_4 mixing ratios (pink, right). Data points are one-year running averages from 1984-2007.

Causes of the Anomalous Atmospheric CH_4 Growth Rate During 2007

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Analysis of global temperature data has revealed that 2007 tied with 1998 for the warmest year on record. Temperatures were exceptionally warm in the Arctic, which experienced a record minimum in sea ice extent during September. It is noteworthy that last year coincided with the cool phase of the ENSO, unlike 1998 when an unusually strong El Niño occurred, bringing with it above average temperatures and precipitation to some northern wetlands, and drought, heat and fires to other wetlands, especially those in tropical Asia. The warm temperatures and above-average precipitation in 2007 appear to have had consequences for atmospheric methane, the growth rate of which increased abruptly in the Arctic, Tropics and southern temperate latitudes.

Since the late 1990s the abundance of atmospheric methane has stabilized with sporadic perturbations such as the 1998 El Niño. Using the TM5 atmospheric transport model, a parameterization of methane emissions from wetlands, and the Global Fire Emission Database v2, we demonstrate that the observed interannual variability in atmospheric methane (apart from long-term trends related to anthropogenic sources) can be explained by the responses of wetlands to climate variability and emissions from biomass burning. Even though biomass burning is a fairly small component of the atmospheric methane budget, its variability is quite large. We show that the methane growth rate anomalies in 2007 were due to anomalous wetland emissions, mainly from far northern Europe, and to a lesser extent from tropical latitudes, Boreal North America and Siberia. About 10 Tg of methane were emitted in the high northern latitudes and over 6 Tg were emitted from tropical wetlands.

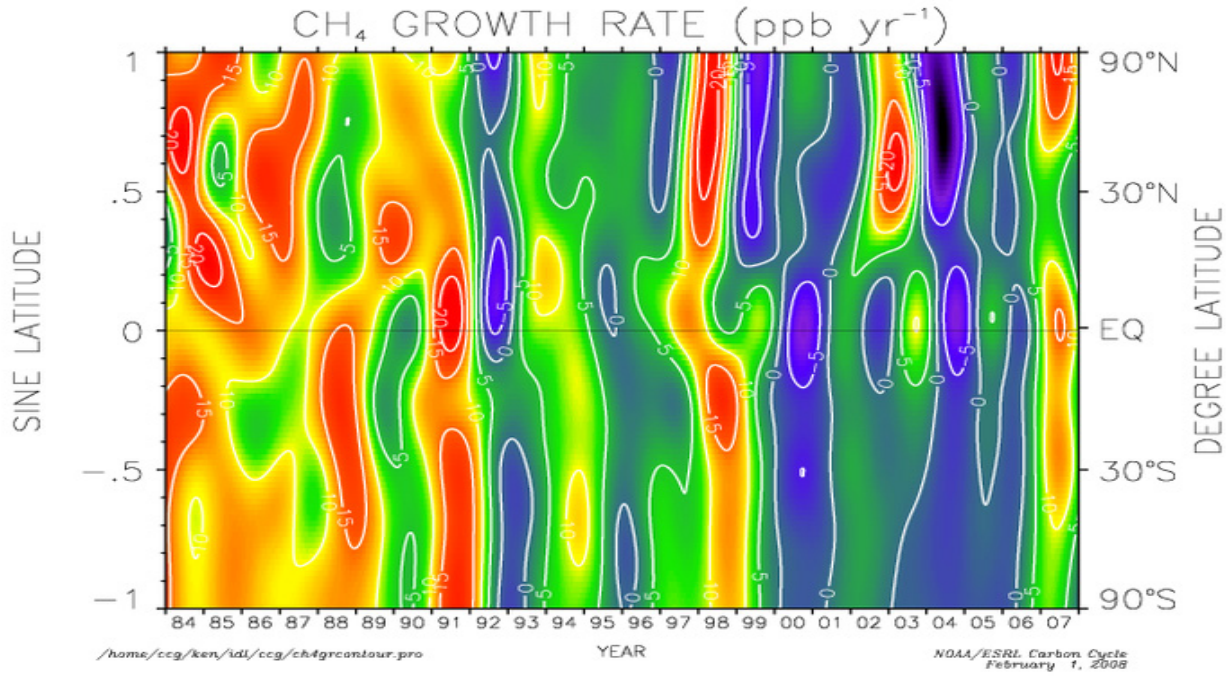

Figure 1. Contour plot of atmospheric CH_4 growth rate, where warm colors are large growth rate and cool colors represent small or negative growth rates. Maximum growth rates are ~20 ppb yr^{-1}; minimum values are ~-10 ppb yr^{-1}. The transition from yellow/orange to blue/green results from a decreasing trend in growth rate.

Looking Down the Tail Pipe of North America: A Case Study for the Use of Offshore Towers to Constrain the North American Carbon Budget

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Prevailing West to East winds across the North American continent suggest that differences in atmospheric carbon dioxide concentrations between air coming onto the West Coast and the air leaving the East Coast will provide a unique constraint on the North American carbon budget. In pursuit of this constraint it has been proposed that a fence comprised of aircraft and tower sites be placed around the perimeter of North America. The offshore tower is particularly appealing as a "fence post" because the local influence of the surrounding water is very small relative to the synoptic influence of air masses coming either from distant land sources and sinks or wide fetch of the ocean. This analysis looks at recent data collected from a 30-m tower off the South coast of Martha's Vineyard and foot prints from Lagrangian Particle Dispersion Models (LPDMs), as well as direct comparisons with Carbon Tracker to determine how synoptic the measured signals are.

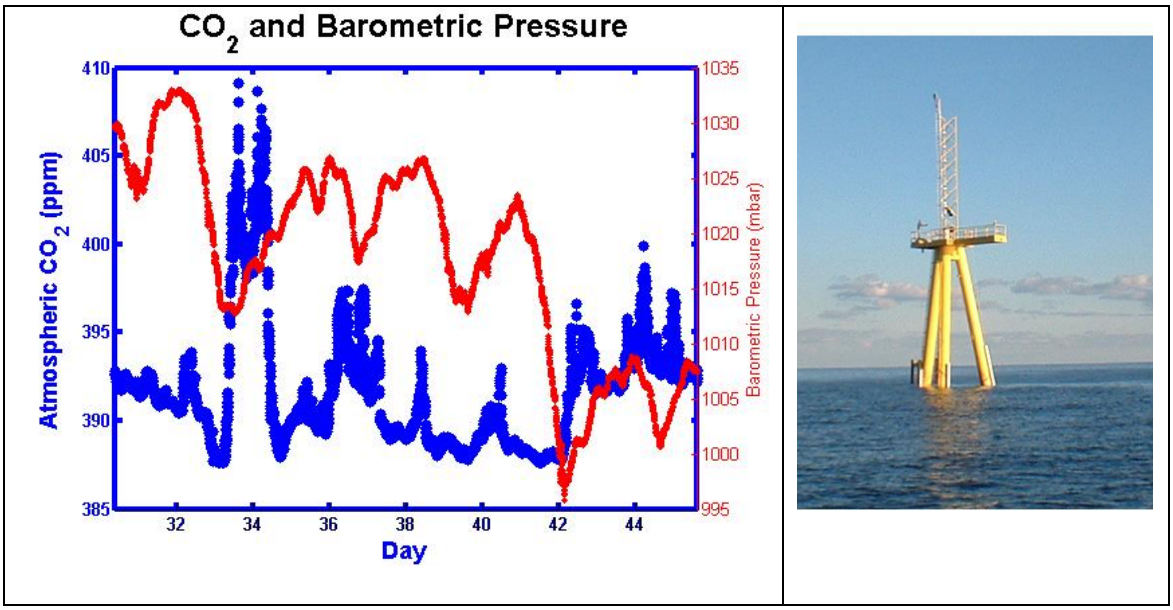

Figure 1. Carbon Dioxide and Barometric Pressure at Martha's Vineyard Observatory (MVO), 3.5 km South of Martha's Vineyard, MA. CO_2 mixing ratio (blue, mole/mole ratio) and barometric pressure measured at 10 m above sea level (red, mbar). The MVO tower mast stands approximately 30 m above the water (15 m depth).

Assessing Terrestrial Ecosystem Responses to Climate Change from Analysis of the Shape and Amplitude of the Seasonal Cycle of Atmospheric CO_2

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We analyzed changes in the shape of the seasonal cycle in atmospheric CO_2 to assess large-scale changes in terrestrial ecosystem function. Monthly mean data from the NOAA ESRL global cooperative air sampling network first were filtered to remove the long term secular trend. Rates of change were then calculated for each month based on linear regressions of monthly residuals versus year. Linear rates of change provide a measure of how the shape of the seasonal cycle has changed through time, with positive rates indicating an increase in monthly CO_2 concentrations and negative rates indicating a decrease. The emphasis on seasonal shape provides a different perspective from methods that focus on the overall amplitude of the seasonal cycle, for which the current method detects changes only when there is a significant trend in the difference between months of maximum and minimum CO_2 concentration. Most stations north of 55º N displayed significantly decreasing summer minima and increasing fall and winter maxima (Figure 1). In contrast, several stations at northern midlatitudes showed the opposite pattern, with shallower summer minima, although these trends were only marginally significant. In an effort to identify the cause of the above changes, we compared observations with climate and soil freeze-thaw anomalies. We also made comparisons with MATCH atmospheric transport model runs forced with historical NCEP meteorology and interannually varying CO_2 fluxes from the CASA and CLM-CN terrestrial ecosystem models.

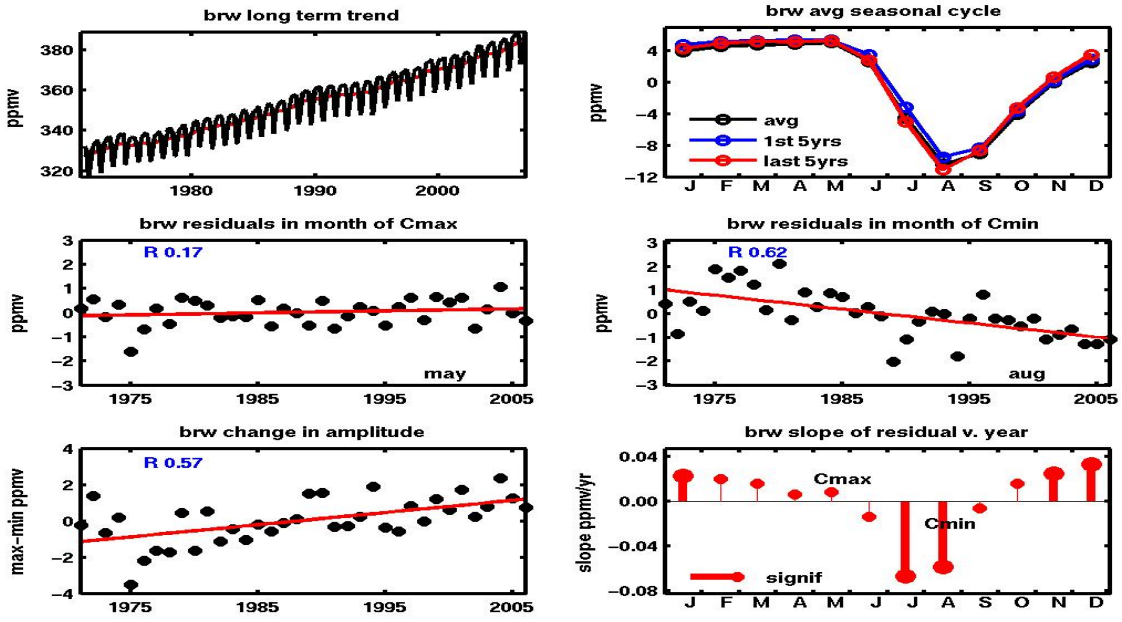

Figure 1. Earth System Research Laboratory atmospheric CO_2 data from Barrow, Alaska (71º N). Upper left panel shows ESRL data and fitted secular trend. Upper right panel shows the average seasonal cycle over the entire record and the first and last five years, calculated from monthly averages of the detrended data. Middle panels show linear regressions on monthly residuals in May (month of Cmax) and August (month of Cmin). Bottom left panel shows linear regression on the difference between the May and August residuals, which is used to estimate the change in amplitude in ppmv/yr. Lower right panel shows the linear slopes in ppmv/yr calculated from residuals for each month. Thick bars indicate slopes significant at the 5% level or better.

Progress of the Greenhouse Gases Monitoring Programme by the China Meteorological Administration (CMA) and Cooperative Projects

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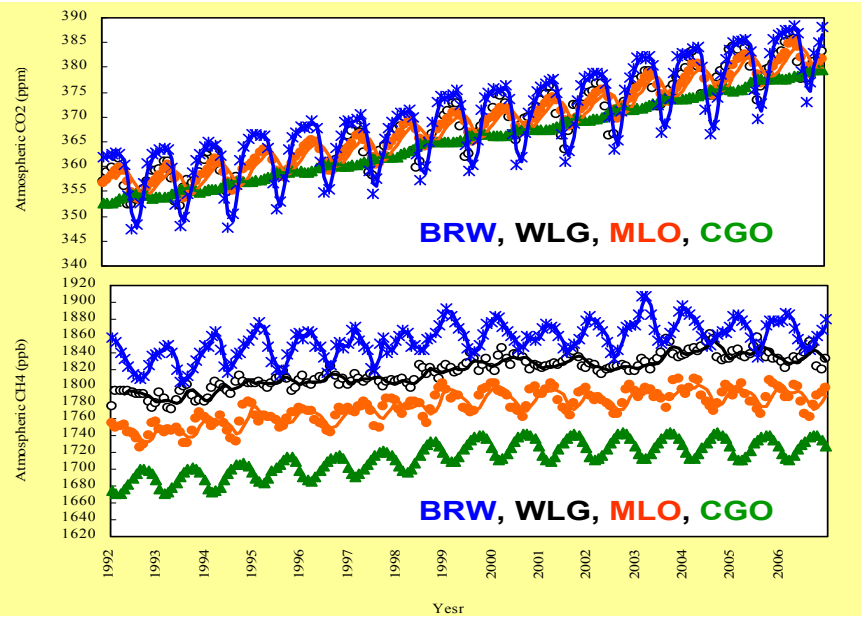
Observational data from GAW stations were widely referenced by the WMO Greenhouse Gases Bulletin and a number of scientific reports. Long-term observation since 1990 validated comparable atmospheric CO_2 and CH_4 mixing rations at Mt. Waliguan GAW global station (WLG, 36.29ºN, 100.90ºE, 3816m asl) in western China to that of other background stations in the globe. From September 2006 to August 2007, preliminary data from grab air sampling at the three GAW regional stations in China showed higher atmospheric CO_2 and CH_4 mixing rations at Shangdianzi (SDZ, 40.39ºN, 117.07ºE, 293.9m asl), Lin'an (LA, 30.3ºN, 119.73ºE, 138m asl), Longfengshan (LFS, 44.73ºN, 127.6ºE, 310m asl), respectively, compared to at WLG. It is inferred that nature and human activities have distinct influence on the China regional background atmosphere. In the past decades, there are kinds of long-term or short period observation and research at a few sites in China conducted by different agencies. However, none of these measurements could effectively document spatial and temporal distributions of greenhouse gases in China and provide essential constraints especially to our understanding of the regional carbon cycle and climate change. Thus, it is essential to establish a long-term observational network at multiple sites in China and to carefully calibrate on internationally agreed reference scales, and quality controlled under the GAW framework. These long-term measurements are of the highest quality and accuracy possible to identify trends, seasonal variability, spatial and temporal distribution, source and sink strengths of greenhouse gases to permit climate and carbon cycle researchers to improve our understanding of the carbon cycle and predict how the atmosphere and climate will evolve in the future as a result of human activities.



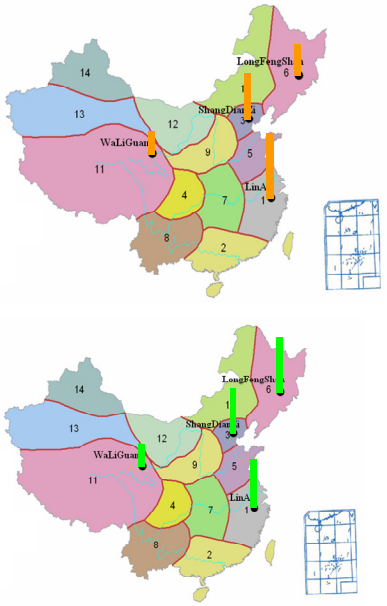


Figure 1 (left). Atmospheric CO_2 and CH_4 mixing ratios at GAW global stations BRW, WLG, MLO and CGO.
Figure 2 (right). Atmospheric CO_2 (top) and CH_4 (bottom) mixing ratios at China GAW stations WLG, SDZ, LA, LSF.

David Hofmann's Pioneering Observations of Stratospheric Volcanic Aerosols

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Volcanic eruptions are one of the two most important natural causes of climate change (the other being solar variations). Our current understanding of the role of volcanic eruptions on climate would not be possible without the pioneering observations of volcanic stratospheric aerosols led by David Hofmann. Hofmann and his colleagues used balloons for *in situ* measurements of the chemistry and size distribution of sulfate aerosols, and these data are used worldwide for climate modeling. In addition, they used lidars for stratospheric aerosol monitoring for decades, and those retrievals depend on knowledge of the aerosol properties obtained by in situ sampling. I will review these observations and explain our current understanding of the role of volcanic eruptions in climate change, pointing out the role of in situ and lidar observations. On a personal note, I feel like I am Dave Hofmann's academic great grandson, having worked in Antarctica measuring ozone and polar stratospheric clouds for Jennifer Mercer, postdoc of Terry Deshler, who was mentored by Dave. I have been to Antarctica once, but Dave has been 19 times, and I feel honored to have been able to follow in his footsteps.

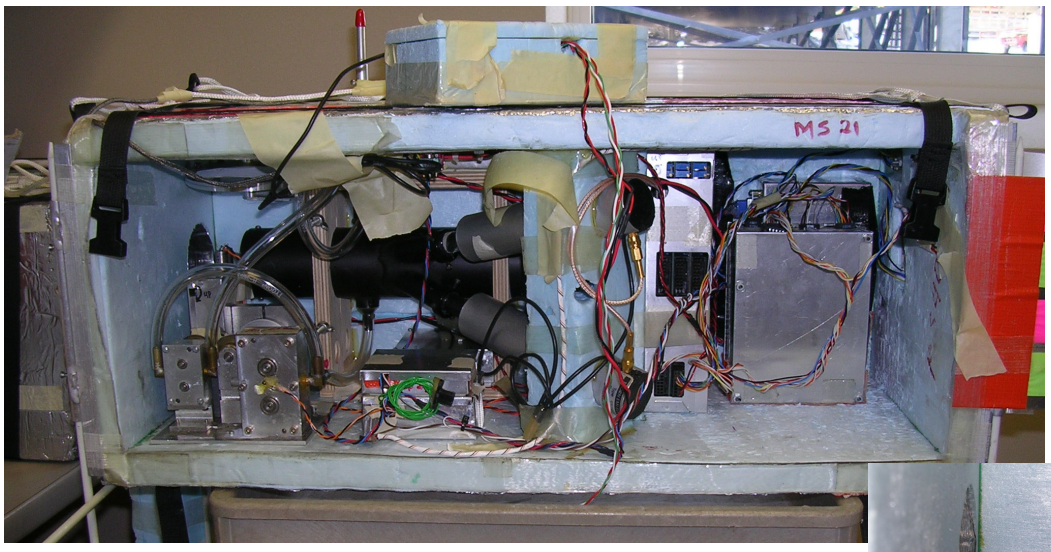

Figure 1. Hand-made University of Wyoming aerosol detector sent up by balloons in Antarctica. They have to be recovered, because of the large investment in each.

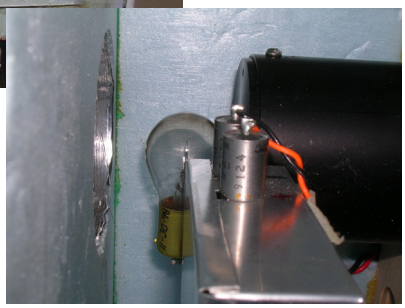

Figure 2. The light source is a 1967 VW taillight bulb, the only source known to produce a completely flat light source.

Stratospheric Aerosol from Pole to Pole: Balloonborne *In Situ* Observations

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Dave Hofmann and Jim Rosen pioneered *in situ* observations of stratospheric aerosol using balloonborne aerosol counters built at the University of Wyoming. They began their measurements in 1971, beginning one of the longest stratospheric aerosol records in existence, Figure 1. In the late 1980s, Dave initiated work to change the scattering angle and increase the flow rate of the instrument, thus extending the measurements to larger sizes and lower concentrations. This "new" instrument has been used to measure: the growth and decay of aerosol from Pinatubo, Figures 1, 2a), and 2b), the present long volcanically quiescent period, Figure 1, the size distributions of the different types of polar stratospheric cloud particles, in both the Antarctic, Figure 2d), and Arctic, Figure 2e), and, most recently, unusually large aerosol particles in the tropical upper troposphere / lower stratosphere, Figure 2c). Efforts are underway to develop a replacement instrument; however, at the moment, this "new" instrument remains nearly the only option to measure aerosol size distributions above 20 km. This talk will describe briefly the development of the "new" instrument and highlight some of the scientific observations made.

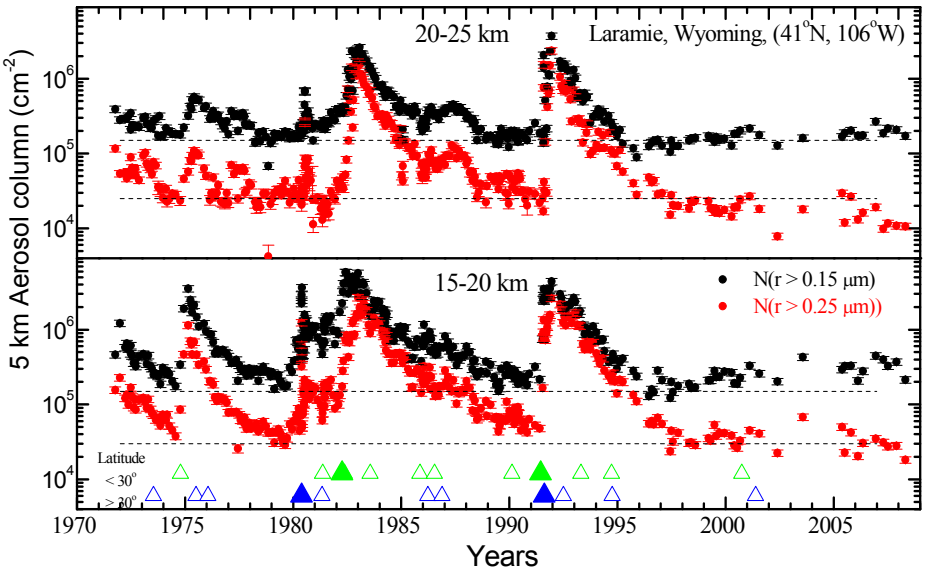

Figure 1. History of stratospheric aerosol above Laramie at 0.15 and 0.25 μm for altitude columns between 15-20 and 20-25 km. Volcanic eruptions in the low latitudes are shown in the green and high latitudes in blue. Solid symbols are eruptions with VEI > 4.

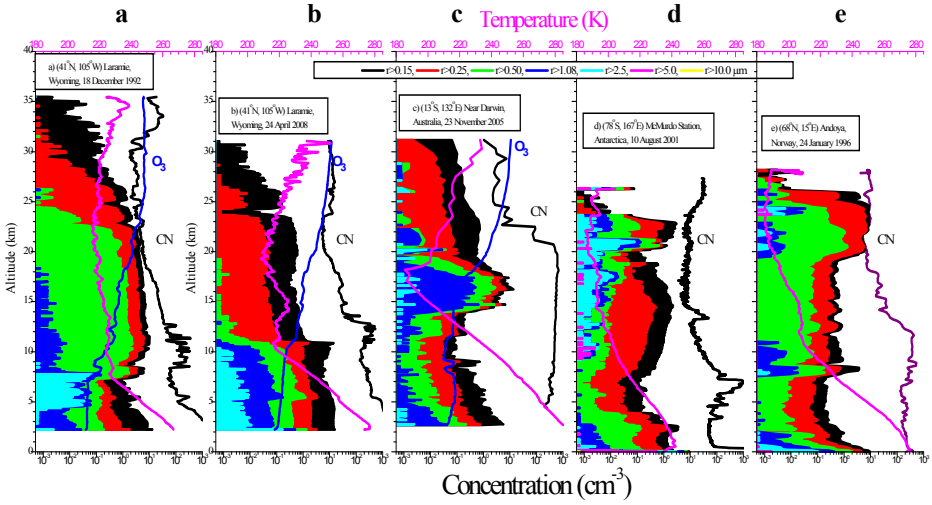

Figure 2. Example aerosol profiles from: mid latitudes a) 1992 and b) 2008, c) tropics, d) Antarctic, and e) Arctic.

Increases in Stratospheric Aerosols

J.E. Barnes[1], D.J. Hofmann[2], and M.S. O'Neill[2]

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Stratospheric aerosols have been measured at Mauna Loa Observatory (MLO) since the 1970's and in Boulder, Colorado since 2000 by the Earth System Research Laboratory. Changes in the stratospheric layer since 1970 have been dominated by two large eruptions, El Chichon in Mexico (1982) and Mount Pinatubo in the Philippines (1991). Eruptions of this scale can increase the mass of stratospheric aerosol by two orders of magnitude. The aerosol then decreases with a characteristic lifetime of about one year so several years are needed to get back to background levels. Influences of small eruptions or injections of forest fire smoke can be seen in the background aerosol, usually near the bottom of the layer, but these only last a few weeks or months. Though both of these have been occurring in the past 12 years there has been an unprecedented well-measured period of no major eruptions since 1996. The MLO lidar shows a significant increase in stratospheric aerosol backscatter between 2000 and 2008 of about 50% or about 8% per year. This amounts to an aerosol optical depth increase from 0.005 to 0.007. The increase is similar at all altitudes in the layer and for all seasons. The layer above Colorado is strongly affected by the changes in the tropopause height but the Boulder lidar shows a similar increase during this time period in the layers well above the tropopause. In the figure below, the annual cycle can be seen in the smoothed curve and in the trend there are three peaks which correlate with the three quasibiennial oscillation cycles that have occurred after 2000, but the overall aerosol backscatter is increasing.

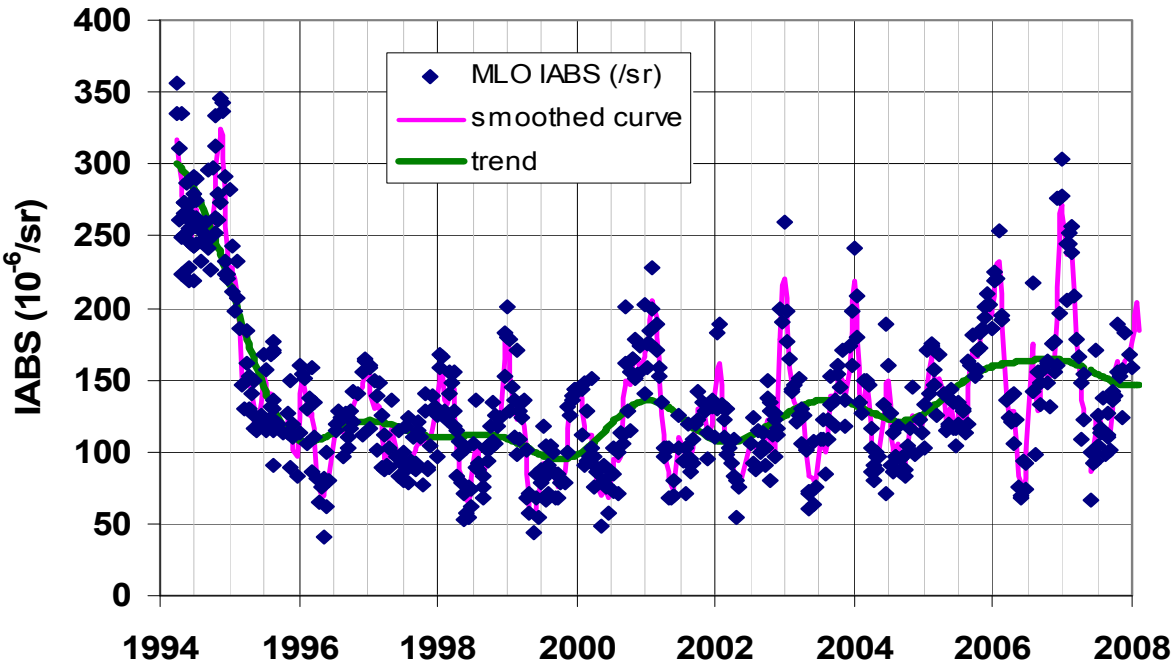

Figure 1. Lidar measurements of Integrated Aerosol Backscatter (IABS) for the stratosphere above Mauna Loa Observatory. The stratospheric layer reached background levels after the eruption of Mount Pinatubo by 1996. Between 2000 and 2008 the backscatter has grown by over 50%.

Stratospheric Ozone Changes from Five Decades of Ground-Based Observations

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Consistent ground-based observations of column ozone began in the US with the predecessors of NOAA during the IGY and have been a key component of the global Dobson spectrophotometer network ever since. Over time other instruments such as the Brewer spectrometer have been integrated into the global total ozone network. In addition reliable ozone vertical profile measurements from balloon-borne ozonesondes, although not nearly as numerous as column measurements, have contributed to the documentation and understanding of the long-term changes in stratospheric ozone that were not foreseen when these ground-based measurements were inaugurated. The scientific curiosity and dogged perseverance of earlier scientists have produced observational records that document the dramatic alteration human activity can bring even to what was thought to be a somewhat remote portion of the atmosphere.

Based on selected stations from the total ozone, ozonesonde, and umkehr measurement networks, long-term changes in stratospheric ozone have been determined. The total column measurements show the significant declines and the more recent flattening of the ozone trend (figure below). The ozonesonde record emphasizes the changes in the lower stratosphere that may include important long-term transport variations as well as changes associated with anthropogenic influences from human-produced halogen compounds. The umkehr observations derived from the Dobson spectrophotometer measurements are most sensitive in the region near 40 km where the depletion and beginnings of recovery linked with human-produced halogens is dominant.

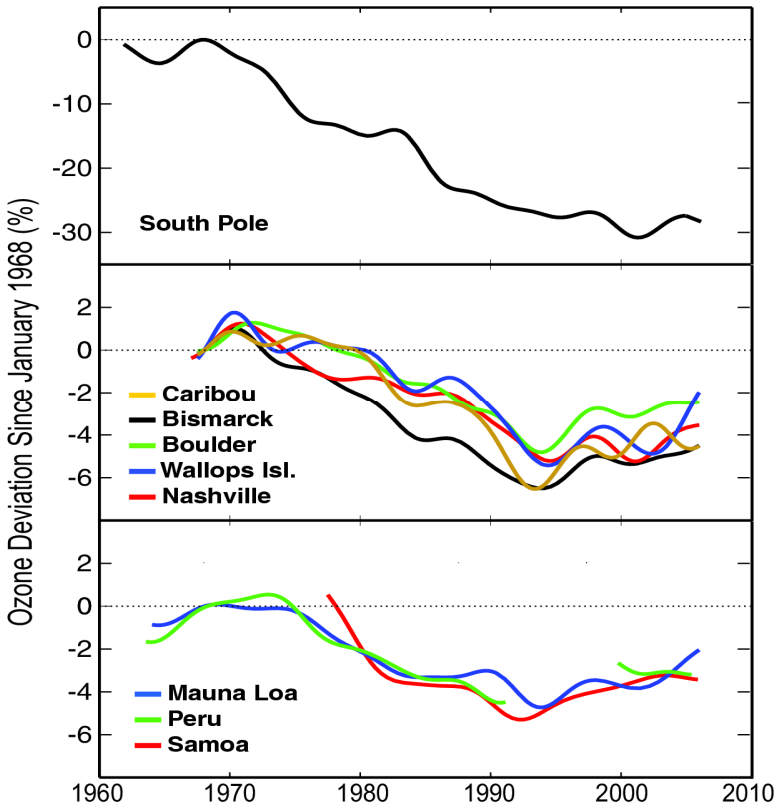

Figure 1. Changes in total ozone from Dobson measurements at South Pole, over the continental US and in the tropics.

Recent Accelerated Growth Observed for HCFCs in the Atmosphere

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In the 15 years before 2004, atmospheric observations had shown steady or, more recently, declining rates of increase for the most abundant HCFCs in the background atmosphere. Since 2004, however, accumulation rates for these gases have increased substantially; global tropospheric growth rates of HCFC-22, HCFC-142b, and HCFC-141b observed in 2007 were 50 to 100% larger than measured in 2004. Particularly surprising are the increases observed for HCFC-142b—global emissions derived for this gas for 2007 from our observations are two times larger than projected in the latest WMO scientific ozone assessment report. HCFC growth rates have *increased* since 2004 despite a large *decrease* (by more than a factor of 3) reported for HCFC production and consumption in developed countries from 2002 to 2006. The enhanced atmospheric increases most likely arise from enhanced HCFC use in developing countries. HCFC production and consumption in developing countries increased exponentially at about 20%/yr over the past decade, accounting for 80% of global HCFC production and consumption by 2006. Most of this HCFC was produced and consumed in China. Additional hints regarding the source of this enhanced emission can be found in the atmospheric data themselves. Small but persistent changes in the atmospheric distribution of HCFC-142b, for example, are discernable in the data. A qualitative analysis suggests an enhanced source since 2004 from low-latitudes in the northern hemisphere, consistent with changes in consumption reported to UNEP over this period. Here we will discuss these results and their implications for ozone depletion and climate. They appear to provide an interesting bellwether concerning the influential role developing countries can and will play in controlling the chemical composition of the global atmosphere.

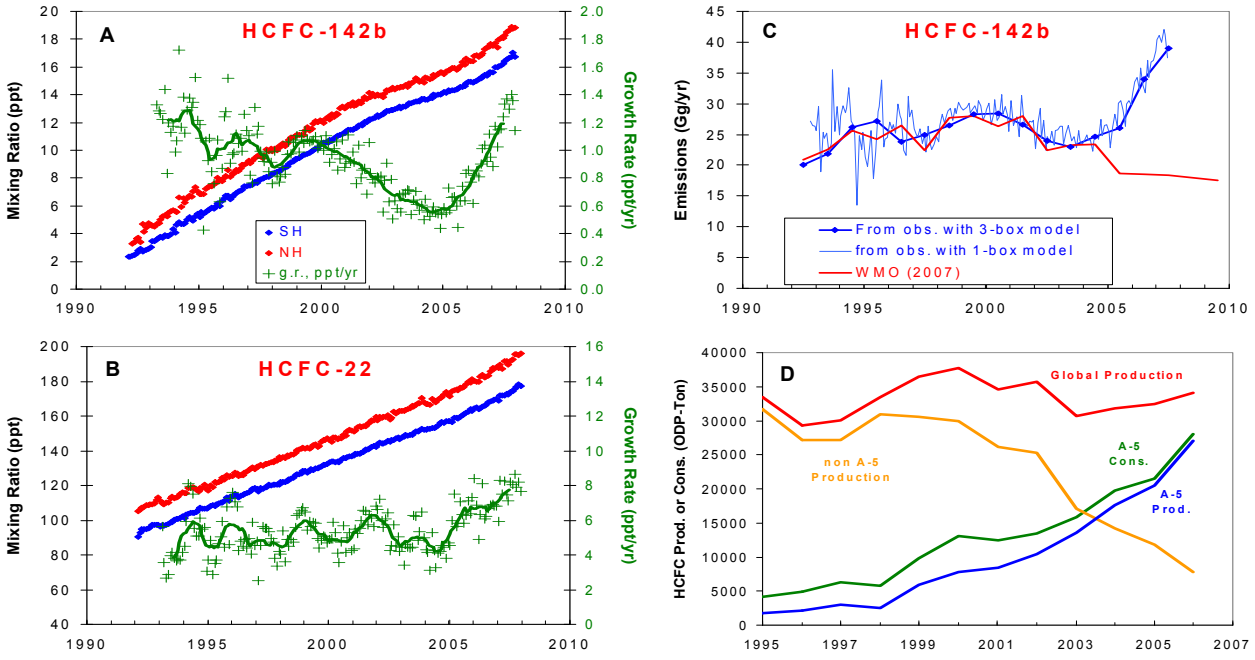

Figure 1. Panels A&B: Measured global tropospheric mixing ratios and growth rates of HCFCs from NOAA's global sampling network; **Panel C**: global HCFC-142b emissions derived from these measurements compared to the baseline scenario in WMO (2007); and **Panel D**: HCFC production and consumption data reported to UNEP during the past decade.

Integrating NOAA's Climate Forcing Observations – The NOAA Annual Greenhouse Gas Index

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As Director of NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL - later to become the Global Monitoring Division of NOAA's Earth System Research Laboratory - ESRL) for nearly 15 years, Dave Hofmann shepherded NOAA's long-term monitoring capability through times of significant change. When he first took the helm of CMDL, it had just been created a few years before, owing to a NOAA reorganization. Later with a new Administration, NOAA was once again reorganized, this time with matrix management. Finally, a few years before Dr. Hofmann's retirement, ESRL was created from six independent laboratories and centers, placing CMDL into the Global Monitoring Division with Dr. Hofmann at the head. Through these changes, however, he always kept his sights on preserving and promoting the value of long-term, climate relevant measurements for addressing scientific challenges, but also for aiding society in its efforts to address global issues such as stratospheric ozone depletion, baseline air quality, and climate change.

One approach to aiding society in its decision-making is to translate the complex language of scientists and try to make it understandable by a broad audience, including educators, policy-makers, and the man-on-the-street. Recognizing the Division-wide attention to accuracy, precision, and representativeness of ESRL GMD's measurements, Dr. Hofmann introduced the NOAA Annual Greenhouse Gas Index (AGGI) to express in simple terms where emissions of long-term greenhouse gases were taking us. The index, now a formal NOAA product anticipated each year by the press, builds upon the concept of radiative forcing, but is applied only to long-lived climate forcing agents. As a product that combines the high-quality, consistent monitoring capabilities throughout the Division, it demonstrates a stark reality – that in 17 years the warming influence of all long-lived greenhouse gases has increased 24% and continues to climb at a rate of about 1.5% per year, despite successes in reducing or eliminating the growth of several species. This presentation will look at how the AGGI is developed and will examine closely its value as a tool for translating science.

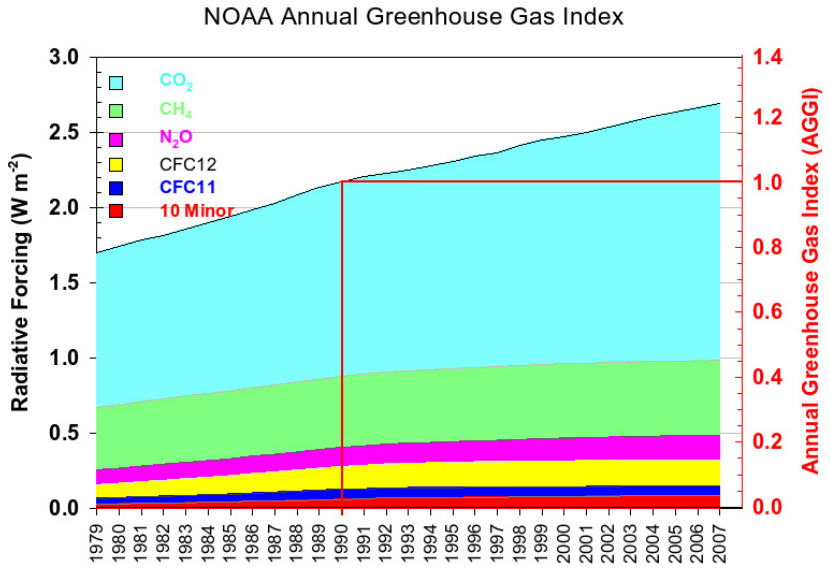

Figure 1. Radiative forcing, relative to 1750, of all long-lived greenhouse gases. The NOAA Annual Greenhouse Gas Index (AGGI), which is indexed to 1 for the year 1990, is shown on the right axis. All measurements are made by ESRL's Global Monitoring Divion

Observationally Closing the Gap Between Climate Radiative Forcing and Changes in Radiation Climate

E.G. Dutton[1] and the ESRL Radiation Group[1,2]

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The collective radiative forcing of climate from a number of sources as shown in the IPCC reports is a few (2-4) W m^{-2} over the period of time that CO_2 is expected to double. However, the resulting actual change in radiation predicted by the ensemble of IPCC climate models over same time is 15-20 W m^{-2}. While the radiative forcing is well-known, being supported by high-quality observations; to date, the larger actual radiation change is only predicted and largely dependent on assumed water vapor feedback. Nonetheless, the expected effects on global temperature have been given a high degree of certainty for currently being detected. Observational confirmation of the actual change in radiation climate along with its spatial variations would contribute to solidifying confidence in predicted climate scenarios as well as allowing better tracking of, and potentially improvements to, those predictions. For the past 15 years, we have been measuring infrared components of the surface radiation budget at a number of globally remote background sites. These data have been analyzed for temporal changes that may be related to model predicted changes. The results are beginning to show observational evidence for a closure of this gap. Details of the observational program and analysis will be presented as well as the preliminary results as summarized in the figure below.

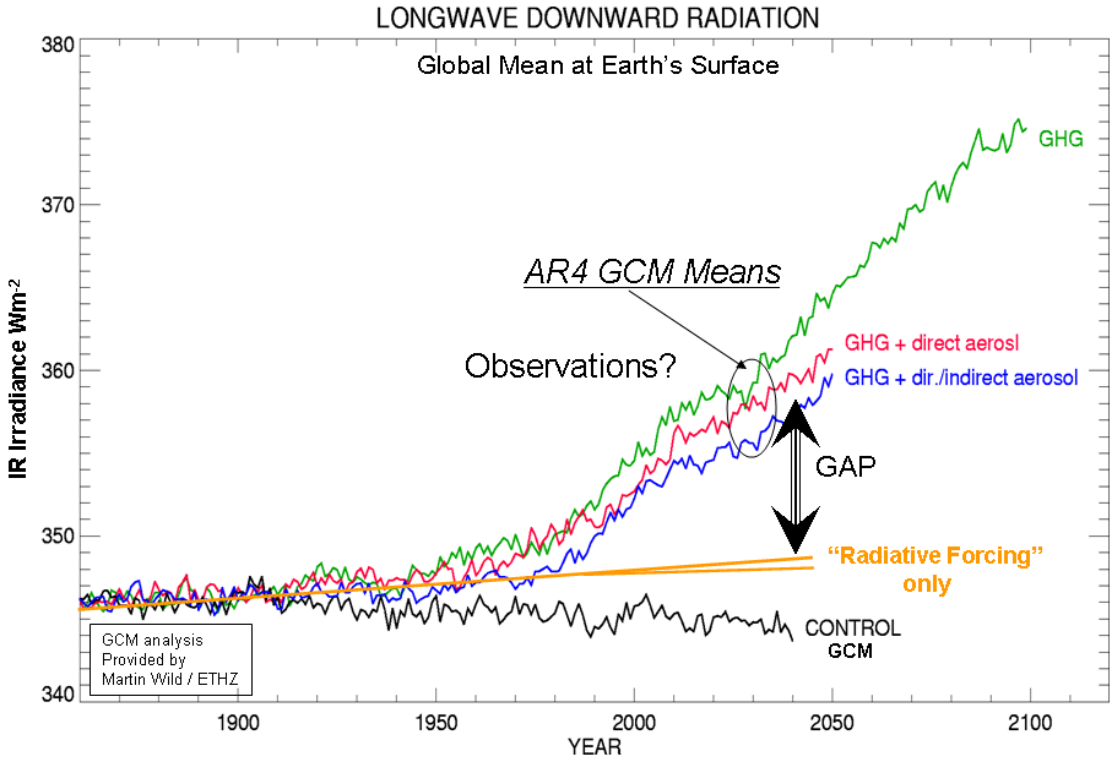

Figure 1. Global mean downwelling thermal IR irradiance as function of time as predicted by the mean of the IPCC AR4 models and that due only to demonstrated radiative forcing with the gap between the two indicated.

Development and Implementation of a Variational Cloud Retrieval Scheme for the Measurements of the SURFRAD Observation System

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[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

The ESRL GMD Surface Radiation Budget Network (SURFRAD) provides continuous and accurate observations of both solar and infrared radiation at seven stations located across the continental United States. Through a combination of upward and downward viewing broadband irradiance measurements, these sites allow a rigorous, long-term characterization of the Earth's surface radiation budget. In addition to these broadband observations, each SURFRAD site also houses a Multi-Filter Rotating Shadowband Radiometer (MFRSR). This instrument, which measures direct and diffuse radiances in six distinct spectral bands in the visible and near-infrared regions, has been used primarily in context of the SURFRAD network to estimate aerosol optical depths via a Langley plot approach. Previous work, however, has suggested that these spectral MFRSR measurements also could be used to retrieve cloud properties. The goal of this work then was to develop and implement a variational cloud retrieval scheme based upon the measurements of the SURFRAD network. Instead of borrowing some pre-existing retrieval technique, however, the ideal combination of measurements for the retrieval scheme was determined through a rigorous error analysis of the surface-based cloud retrieval problem. The optimal retrieval scheme was applied both to synthetic data to determine our theoretical ability to retrieve cloud properties from these measurements and to SURFRAD radiance measurements to determine observed cloud properties with associated uncertainties at each station. These results were then compared to those from satellite-based observations such as MODIS from both a theoretical and observational perspective. In addition, to gain a better characterization of surface albedo and its effects on retrievals, a downward looking MFRSR was installed at the SURFRAD Table Mountain station to constrain the standard upward measurement. The figure below shows theoretical results for the expected retrieval accuracy of cloud visible optical depth as a function of cloud optical depth and effective radius from the SURFRAD MFRSR based upon an initial error analyses.

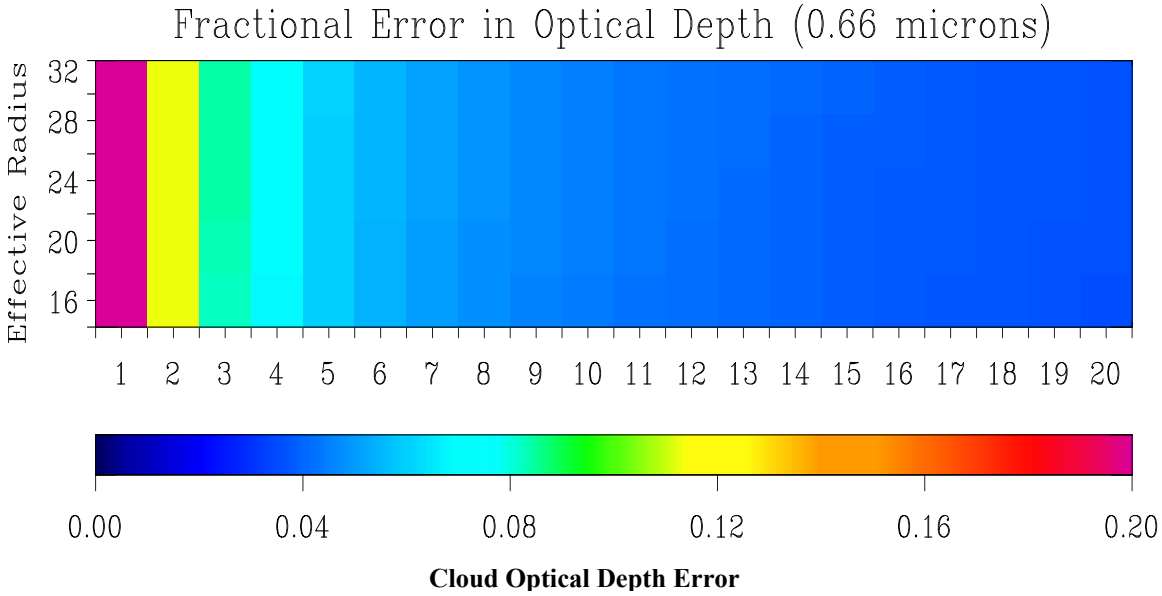

Figure 1. Theoretical results for the expected retrieval accuracy of cloud visible optical depth as a function of cloud optical depth and effective radius from the SURFRAD MFRSR based upon an initial error analyses

Comparison of UV-RSS Spectral Measurements and TUV Model Runs for the May 2003 ARM Aerosol Intensive Observation Period

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The first successful deployment of the ultraviolet rotating shadow-band spectroradiometer (UVRSS) occurred during the May 2003 U.S. Department of Energy's Atmospheric Radiation Measurement program's Aerosol Intensive Observation Period. The aerosol properties in the visible range were well characterized using many instruments to determine the column aerosol optical depth, the single scattering albedo, and the asymmetry parameter needed for radiative transfer calculations of the downwelling direct normal and diffuse horizontal irradiance in clear-sky conditions. We used the Tropospheric Ultraviolet and Visible (TUV) radiation model developed by Sasha Madronich and his colleagues at the U.S. National Center for Atmospheric Research for the calculations of the spectral irradiance in the ultraviolet. Since there were no ultraviolet measurements of the aerosol properties, except for aerosol optical depth, the input data used in the radiative transfer model are based on the assumption that we can extrapolate from the visible portion of the spectrum. There is no consensus extraterrestrial irradiance spectrum to use for the TUV model, instead, the measured and modeled transmittance spectra between 300 and 360 nm are compared for seven cases that included variable aerosol loads and high and low solar-zenith angles.

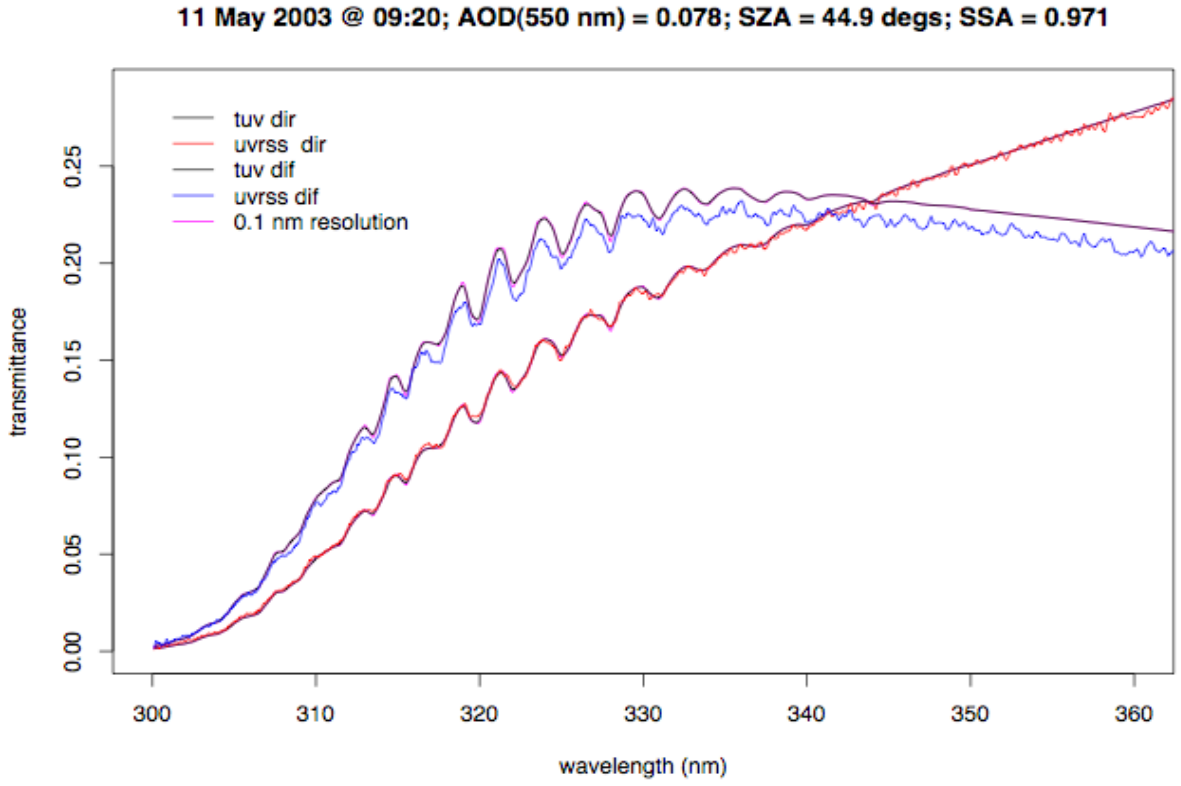

Figure 1. The UVRSS measured direct and diffuse transmissions for the graph's title conditions are in red and blue, respectively. The modeled values at the UVRSS resolution are in black. The magenta lines are at the 0.1-nm resolution of the model. The direct model and measurements agree indicating that extinction is correct; the difference between diffuse model and measurements indicate that model inputs are incorrect.

Comparison of Aerosol Vertical Profiles from Spaceborne Lidar with *In Situ* Measurements

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NOAA began regular, *in situ* measurements of aerosol vertical profiles over Illinois with a light airplane in June, 2006. By late February, 2008, over 200 profiles of aerosol light scattering and absorption coefficients, hygroscopic growth factor for scattering, particle number concentration, and number size distribution had been obtained, and many of the flights included measurements of aerosol ionic composition. In addition to the primary objective of obtaining a climatology of aerosol properties aloft for evaluating aerosol radiative forcing and testing chemical transport models, the program has a secondary objective of evaluating aerosol measurements from satellites. Many of the profiles are located and timed to coincide with overflights of the A-Train constellation of satellites. Comparison of the *in situ* measurements with profiles derived from the CALIOP lidar on the CALIPSO satellite suggest that the lidar can reliably detect layers with aerosol scattering levels above about 25 Mm^{-1}. The long-term climatology of surface aerosols at the Bondville, IL monitoring site indicates that aerosol loadings are above this threshold roughly 70 percent of the time. At more remote sites, data from the NOAA long-term aerosol monitoring network (figure) indicate that the lidar will rarely report a detectable aerosol signal.

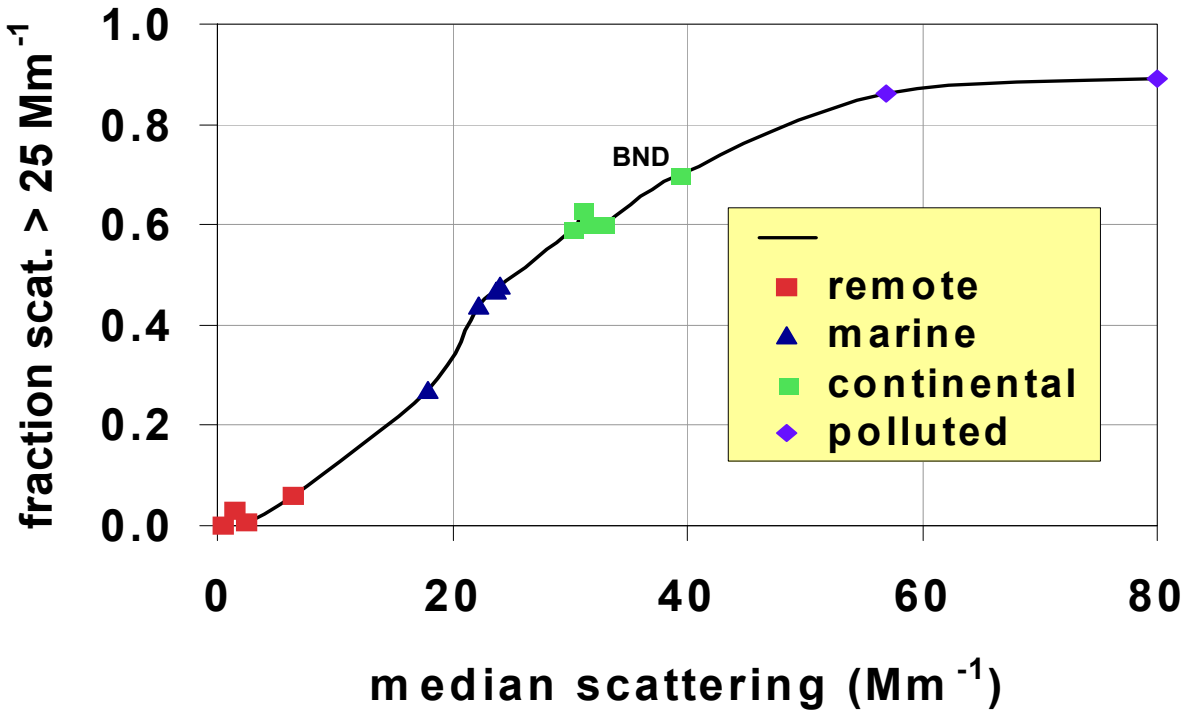

Figure 1. Fraction of observations when aerosol light scattering is above CALIPSO threshold of 25 Mm^{-1}.

Elemental and Organic Carbon Measurements in Fine PM from Urban to Rural to Background Air Over Canada: Understanding Human Impacts on Atmospheric Compositions

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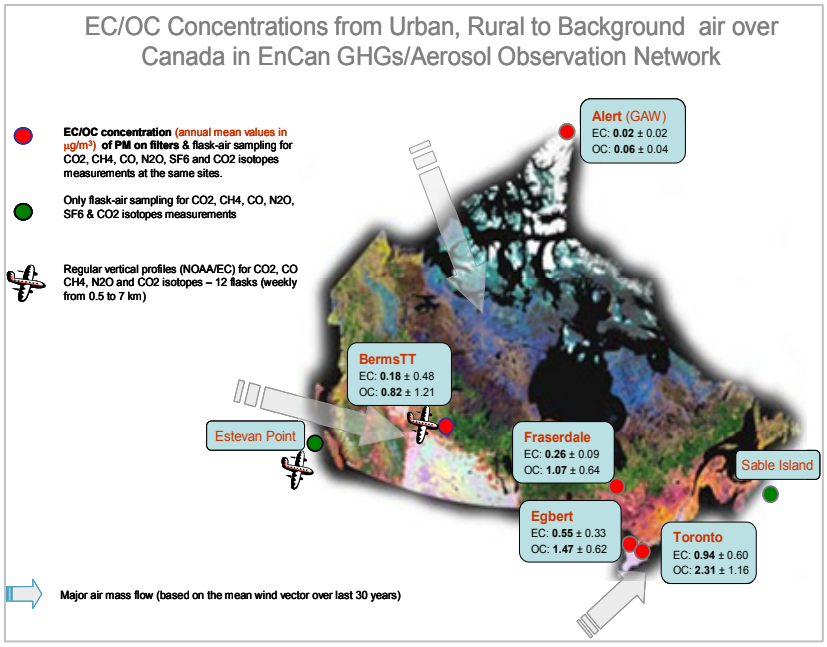
Quantifying human induced CO_2 and other air pollutants in ambient air is important in air quality and climate change research, particularly in addressing the issue of the continued increase of atmospheric CO_2. Elemental and organic carbon (EC & OC) components in fine carbonaceous particulate matter (PM) are key air pollutants, existing in urban, rural and remote environments. It is known that they are released from various emission sources (e.g., fossil fuel combustion, biomass burning, primary biological matter) and also produced in the atmosphere from photochemical oxidation of gas phase organics. Tracking their spatial (e.g., from urban to rural to background air or latitudinal) and temporal (e.g. seasonal and inter-annual) distributions will provide valuable information for constraining their emission strength and propagation mechanisms, assessing the impact of human induced emissions on current ambient concentrations or deposition rates, as well as in evaluating the effectiveness mitigation actions of these pollutants.

Quartz filter samples were collected for one year (2006-2007) at five sites in Canada (see the map), from Toronto (a typical urban site), Egbert (a rural site, ~ 80 km northwest of Toronto), to Fraserdale, and Berm-TT (both are continental boreal forest sites), to Alert (an Arctic baseline site). EC/OC concentrations were determined using a thermal/optical method. The magnitude of pyrolized organic carbon (POC), which is produced in the analysis and proportional to oxygenated OC on the filters, was also obtained from these measurements. A subset of the samples was selected for $\delta^{13}C$ measurements in each carbon fraction (i.e., OC, POC and EC). The EC & OC measurements have been co-located with measurements of aerosol optical properties and greenhouse gas concentrations. It is anticipated that these measurements will continue to be part of long-term measurement program in Environment Canada's GHGs & Aerosol Observation Network allowing an integrative approach to track and assess the human impact on climate change.

The spatial and temporal distributions, including annual means and the seasonal variations of EC, OC, POC and their related ratios (e.g. OC/EC, POC/OC), were derived. Combined with the $\delta^{13}C$ information, it was found that the spatial gradients of EC and OC (shown on the map) during different seasons from urban, rural and background air over Canada were mainly due to the propagation of human induced emissions for the period of observation. However, biomass burning and biogenic emissions, as primary sources, and atmospheric photochemical oxidation processes play important roles in influencing seasonal variations at the different sites.



Similar measurements for the same period of time from Beijing, a mega-city in China, and the average value for a two-month (April-May, 2006) at Whistler Mountain on the west coast of Canada, will also be shown to provide insight on the impact of long-range Asian-Pacific transport on the ambient levels of EC/OC over Canada.

Atmospheric Monitoring of the Malaysia Meteorological Department, Ministry of Science, Technology and Innovation, Malaysia.

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The Malaysian baseline Global Atmosphere Watch (GAW) station in Danum Valley, Sabah was established in October 2004. It is located at latitude 4° 58' 53" North, longitude 117° 50' 37" East, elevation 426m above MSL in the State of Sabah, Malaysia. The station is in a conservation area surrounded by tropical lowland forest. The goals of establishing the GAW station in Danum Valley are to obtain long-term, reliable, comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere on a global scale.

Figure 1. Danum Valley, Sabah GAW staion.

At present, the GAW station monitors the following parameters:

1. Carbon dioxide using the Australian LoFlo System with intakes at three levels.
2. CFCs, Methane and Nitrous oxide by flask sampling and analysis by the University of Tokyo, Japan.
3. Precipitation chemistry with the Ecotech wet-only collector and analysis by the national laboratory for the East Asia Acid Deposition Network (EANET).
4. Aerosol characteristics such as aerosol loading, back scattering, black carbon and aerosol optical depth.
5. Reactive gases by filter-pack method for EANET.
6. Persistent organic pollutants by passive sampling.
7. Surface ozone
8. Meteorological parameters with the Viasala Automatic Weather System

The station is also part of the East Asia Acid Deposition Monitoring Network (EANET) and supports research activities that are conducted at the Danum Valley Field Centre by scientists from the British Royal Society, which manages the centre. Total column ozone and UV radiation measurements using the Mark II Brewer Spectrophotometer No. 90 are carried out at the urban station in Petaling Jaya while ozone profile soundings using the Vaisala Digicora system are made twice a month at the Kuala Lumpur International Airport Meteorological Station.UV-B and ozone data from the measurements made by the Brewer Spectrophotometer and the sondes since 1992 are submitted to the world data centres regularly. A number of joint studies and papers were published based on the information generated by this activity.

GAW Activities at Empa

J. Klausen[1], C. Zellweger[1], S. Henne[1], A.F. Ilahi[2], C. Siregar[2], H. Hamza[2], M. Mimouni[3], M.S. Ferroudj[3], J. M. Kariuki[4], J.O. Aseyo[4], and B. Buchmann[1]

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QA/SAC Switzerland and WCC-Empa contribute to WMO's GAW programme – inter alia – with the GAW Station Information System (GAWSIS), auditing and calibration of global GAW sites for the parameters surface ozone, carbon monoxide, methane and nitrous oxide (the latter in collaboration with WCC-N_2O), and active twinning partnerships with the global GAW sites Bukit Koto Tabang (Indonesia), Mt. Kenya (Kenya) and Assekrem (Algeria). This presentation will give an update on the functionalities of GAWSIS and the integration with the GAW World Data Centres; recent activities of WCC-Empa with respect to maintaining the traceability of the global network; and discuss results of our collaboration with selected GAW stations in developing countries.

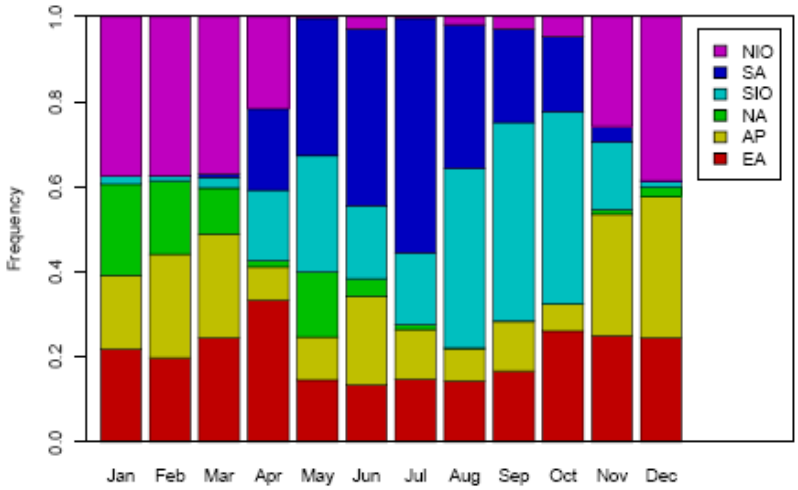

Figure 1. Annual cycle of the relative frequency for different trajectory clusters identified for Mt. Kenya GAW station (MKN), documenting the distinct seasonal pattern of the monsoon flow over the Indian Ocean. NIO: Northern Indian Ocean; SA: Southern Africa; SIO: Southern Indian Ocean; NA: Northern Africa; AP: Arabian Peninsula; EA: Eastern Africa

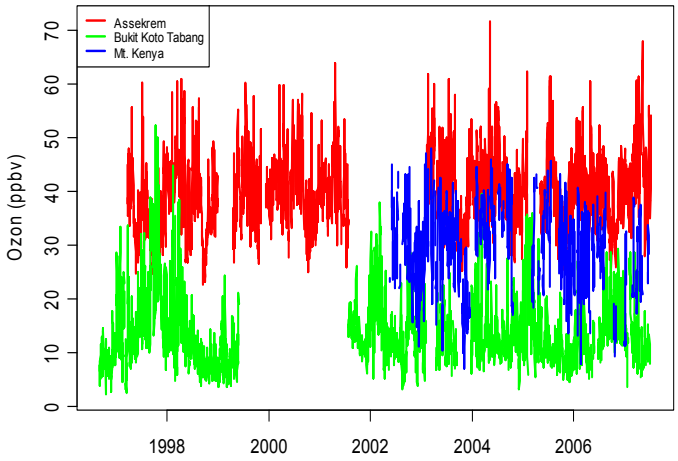

Figure 2. Time series of surface ozone observed at the global GAW Stations Assekrem (Algeria, 2770 masl), Bukit Koto Tabang (Indonesia, 964 masl), and Mt. Kenya (Kenya, 3678 masl). The different ozone levels and the variation of ozone concentrations reflect the different setting of these sites in terms of geographical location and altitude, as well as different ozone production and destruction regimes.

Quality Assurance and Quality Control in the WMO-GAW-VOC Network

R. Steinbrecher and S. Thiel

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Tropospheric volatile organic compounds (VOC) are one of the recommended measurements to be made at global stations under the Global Atmosphere Watch (GAW) programe of the World Meteorological Organization (WMO). The purpose is to monitor their atmospheric abundance, to characterize the various compounds with regard to anthropogenic and biogenic sources for evaluating their role in global tropospheric ozone. Because of their relatively short residence in the troposphere, a representative global background level can not be easily established, since it would require hundreds or even thousands of measurement sites. Therefore, the objective of GAW-VOC monitoring is to produce high quality data with known uncertainty at specific representative sites for major biomes. Reported mole fractions and compound ratios of VOC are then used for characterization of the photochemical age of air masses and transport processes. Furthermore, those data are needed as input for global/regional climate modeling based on Chemistry-Transport-Models (CTM) to validate their performance, e.g. for understanding the OH-radical, ozone and SOA distributions.

The GAW QA/QC procedures are in line with the following principles: (1) to use internationally accepted methods and vocabulary to describe the uncertainty in measurements; (2) to harmonize the measurement methodology at stations by using measurement guidelines (MGs) and standard operating procedures (SOPs); (3) to conduct regular performance and system audits aimed at checking the station's agreement with the GAW QA/QC system.

The WCC-VOC does not aim at maintaining its own calibration scale, but will be linked to the VOC scale maintained by the Central Calibration Laboratories to be established. Further information about the WCC-VOC can be obtained from http://imk-ifu.fzk.de/wcc-voc/. Some results from recent audits and inter-comparisons at GAW-stations will be presented and discussed.

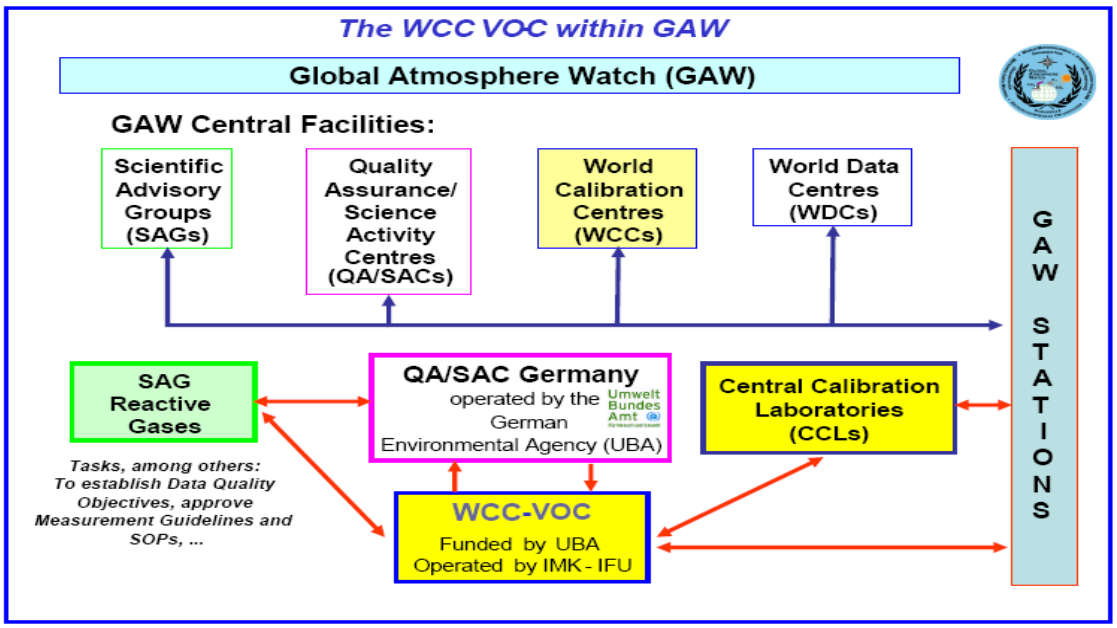

Figure 1. The Global Atmosphere Watch network and its QA/QC system.

Climate Variability in the Region of Future Tiksi Hydrometeorological Observatory from a New Digital Archive of Meteorological Data - Sakha Republic, Russia

A. Makshtas[1], N. Ivanov[1], S, Shutilin[1], and T. Uttal[2]

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Roshydromet and NOAA have developed a formal collaborative project entitled "Establishing a Modern Weather Station and Research Observatory in Tiksi, Russia". This joint project exists under the framework of the NOAA-Roshydromet Memorandum of Understanding for Cooperation in the Areas of Meteorology, Hydrology and Oceanography. A significant contribution to this project has been a Roshydromet project to create an electronic archive of standard meteorological observations from 1932 to 2007 from the original, non-digital records. Presented here are preliminary results of statistics calculated for air surface temperature, surface pressure, wind velocity, and cloudiness. The preliminary analysis indicates that the distribution of probabilities for all months is single modal, and seasonal variability is captured in the evaluations of not only mean values, but also in dispersions and extremes. Quantile analysis allows the specification of synoptic influences on the distribution characteristics and the variability of climatic characteristics in the area under study. It is shown for instance, that asymmetry in air temperature distribution in summer is determined substantially by large positive temperature anomalies. The analysis of wind velocity has shown anisotropy of the distribution by wind direction with strongest winds from the South-West. Strongest winds (up to 35 m/s) as well as the highest frequency of calm conditions are observed in winter. Both winter and summer seasons have small positive trends in surface air temperature, and winter has a pronounced increase in maximum and decrease in minimum surface air temperatures. One of the most interesting features is the strong decrease (from nine to six tenths) of total cloudiness and an increase of specific humidity in summer. The new Tiksi data has also been used to specify the dates of fast ice formation (in fall) and breakup (in spring) in the AARI thermodynamic sea ice model. This in combination with local climatic information regarding temporal variability of snow thickness on sea ice in has resulted in significant improvements in the ability of the model to adequately reproduce the time evolution of fast ice thickness. This new digital archive of meteorological data for Tiksi will provide a historical foundation for analysis of measurements in the new Tiksi Observatory. In addition, it will be an important resource in determining an operations plan for new monitoring efforts at the new Tiksi Hydrometeorological observatory as it evolves into a climate observatory to support circum-Arctic observations.

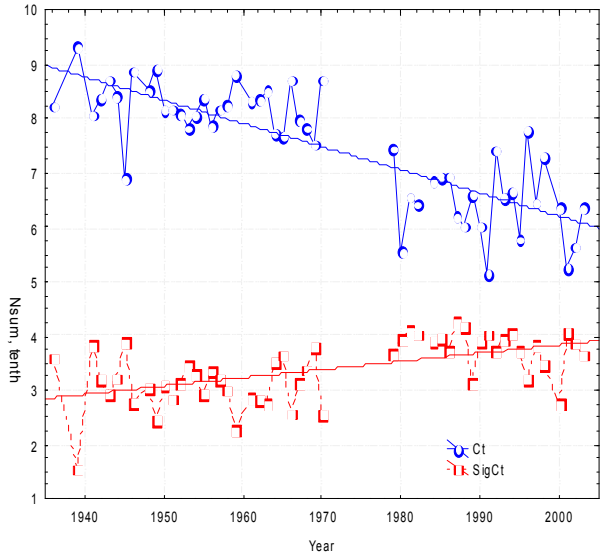

Figure 1. Total Cloudiness in summer.

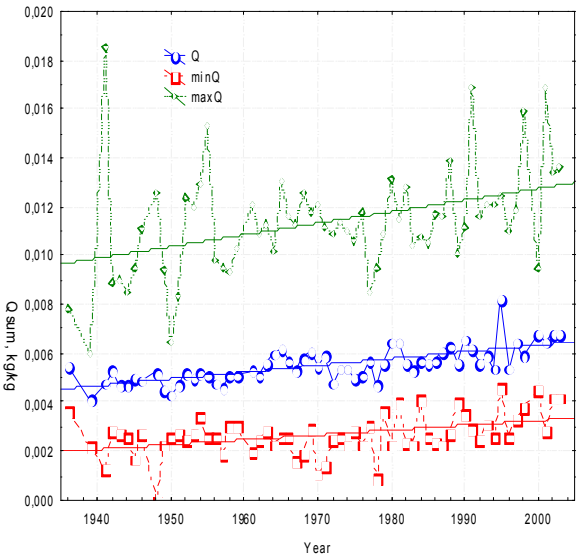

Figure 2. Specific Humidity in summer.

Observations of Mercury Species and Halogens at Summit, Greenland

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During May and June 2007 a field campaign was carried out at Summit, Greenland, to investigate the importance of halogens and mercury chemistry in this remote environment. Instruments were deployed to obtain a large suite of observations that included: Hg (gaseous elemental, reactive gaseous, and particulate-bound), BrO, OH, RO_2, CO, NO, O_3, HCl, HNO_3, HO_2NO_2, SO_2, soluble bromide, snow ionic composition, and J values. Significant levels of BrO (up to 5 pptv) were often observed by both a differential optical absorption spectrometer (DOAS) and a chemical ionization mass spectrometer (CIMS). Depletion of elemental mercury and production of reactive gaseous mercury was observed daily. These results indicate that halogen-mercury chemistry is active at Summit during summer.

These were the first-ever monitoring of reactive gaseous mercury (RGM), fine particulate mercury (FPM), and gaseous elemental mercury (GEM) concentrations at Summit. Under sunlight conditions bromine gas dissociates, catalyzes the destruction of ozone, and oxidizes gaseous elemental mercury (GEM or Hg^o) to reactive gaseous mercury (RGM) via:

$$Br_2 + h\nu \rightarrow 2Br;\ Br + O_3 \rightarrow BrO + O_2\ ;BrO + BrO \rightarrow Br_2 + O_2$$

or

$$Hg^o + Br \leftrightarrow HgBr \text{ (radical precursor to RGM, favored by cold temperatures)}$$

The newly formed RGM then deposits rapidly to the snow pack with a high deposition velocity (~1-2 cm/s), or becomes bound to airborne particles forming fine particulate mercury (FPM). At Summit we detected well-defined RGM peaks at maximum solar elevations, and broad FPM enhancements at minimum solar elevations. After midday RGM production, when the surface snow was greatly enhanced with oxidized mercury, GEM concentrations in the near surface air commonly showed sharp peaks caused by mercury photoreduction within the top few centimeters of the snow pack.

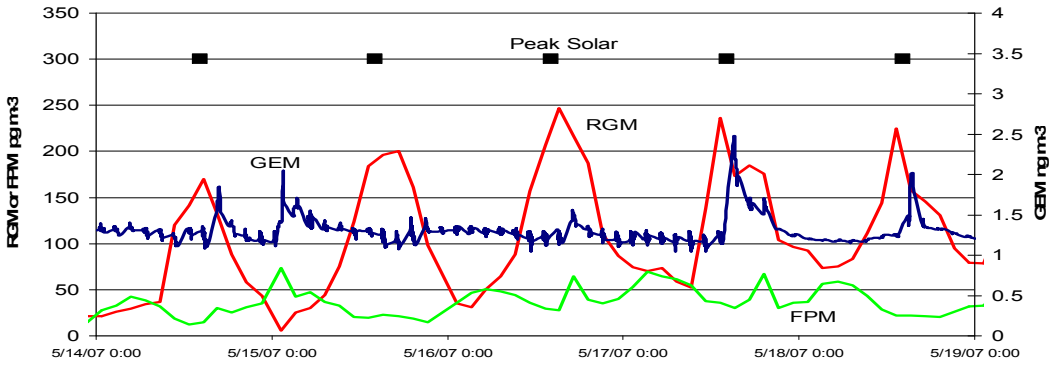

Figure 1. Mercury Speciation at Summit May 14-19, 2007.

In Situ Ground and Aircraft Observations of Carbonyl Sulfide (COS): Evidence for Uptake

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Carbonyl sulfide (COS) is an important trace gas in the atmosphere, because it is a strong infrared absorbing gas and contributes to 25-50% of the total source stratospheric sulfate aerosol layer, which also catalyzes stratospheric ozone depletion. Atmospheric levels of COS have increased about 150-200 ppt in the atmosphere since the industrial revolution of the 1750s . The increase may be related to enhanced emissions of sulfur from fossil fuels and other industrial activities. While the trace gas COS has the strongest direct positive climate forcing of all of the minor greenhouse gases (SF_6, HFCs, HCFCs, solvents, halons), it has a negative indirect climate forcing because it is a source of stratospheric sulfate aerosols that can cool the atmosphere. COS has a strong seasonal cycle because there is strong uptake by plants similar to the CO_2 uptake during photosynthesis. Our understanding of gross terrestrial primary production may be improved through the study of atmospheric COS. This talk will focus on recent ground based *in situ* observations from NOAA ESRL baseline observations and *in situ* airborne observations from the tropics and polar regions that show a pattern of uptake at the surface. For example in the Pt. Barrow, Alaska high frequency observations shown below, this pattern is seen during the period of high seasonal emissions of chloroform (green) where snow has melted and surface vegatation is exposed, which permits photosynthetic uptake and depletion of CO_2 (black) and COS (red) in air masses originating over the arctic tundra.

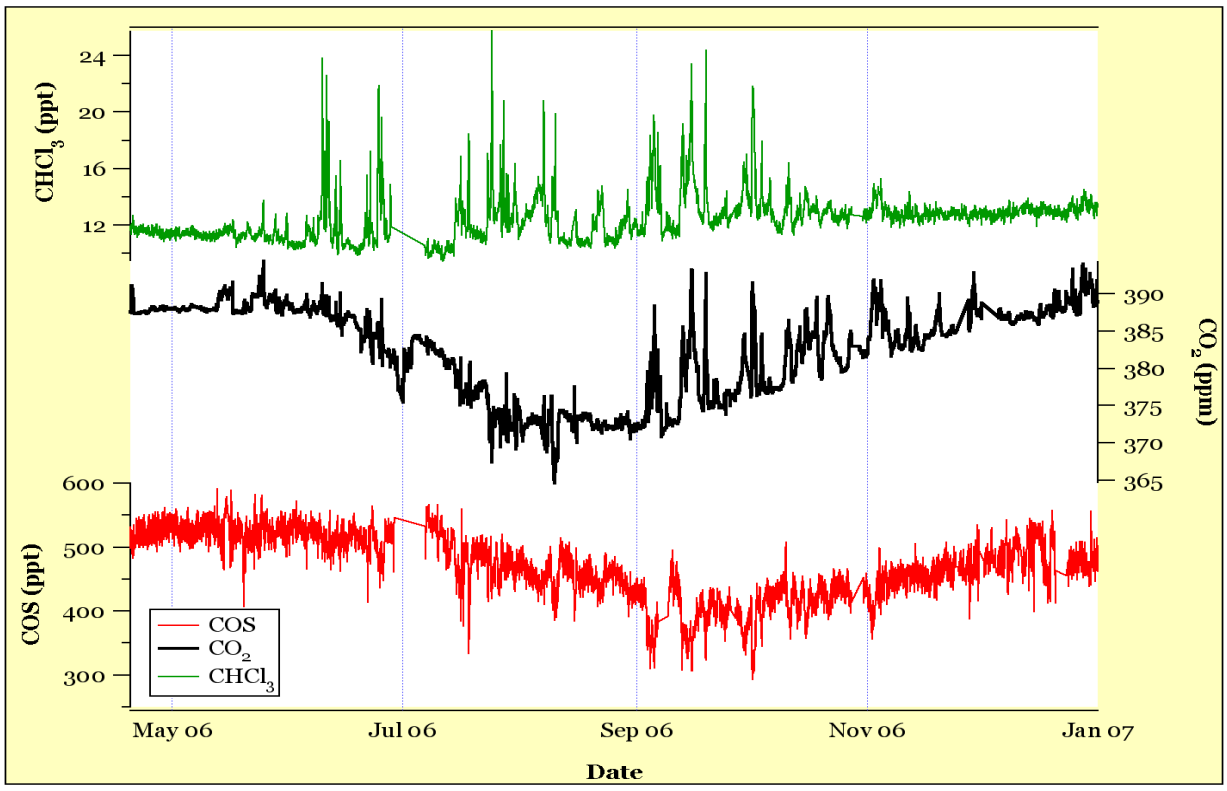

Figure 1. Concentrations of $CHCl_3$ (green), CO_2 (black), and COS (red) at Pt. Barrow, Alaska in 2006.

Selected Results from Trace Gas Inter-comparisons Between AGAGE *In Situ* and NOAA Flask Data

P.B. Krummel[1], L.P. Steele[1], P.J. Fraser[1], L.W. Porter[1], N. Derek[1], S.A. Montzka[2], E.J. Dlugokencky[2], G.S. Dutton[3], B.D. Hall[2], J.W. Elkins[2], B.R. Miller[3], P.K. Salameh[4], J. Mühle[4], C. Harth[4], R.F. Weiss[4], S. O'Doherty[5], P.G. Simmonds[5], B.R. Greally[5], and R.G. Prinn[6]

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[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
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It is becoming increasingly important to accurately merge atmospheric trace gas data sets from different laboratories and different calibration scales to use them for global interpretative and inverse modeling studies in order to determine sources and sinks of these trace gases. To facilitate this, on-going inter-comparisons of *in situ* data with independent flask and/or *in situ* data collected at common sites are useful as they are sensitive diagnostic tests of data quality for the laboratories involved, and they provide the basis for merging these data sets with confidence.

For the past 8 years up to 250 inter-comparisons of non-CO_2 greenhouse gases have been carried out twice yearly and presented at meetings of AGAGE scientists and cooperating networks. The majority of these inter-comparisons are between AGAGE *in situ* and NOAA flask data (HATS and CCGG) at the five common measurement sites; Cape Grim, American Samoa, Barbados, Trinidad Head and Mace Head.

In this presentation the inter-comparison methods will be outlined and results from selected comparisons will be shown. A brief summary of the overall level of agreement between AGAGE and NOAA data will be given.

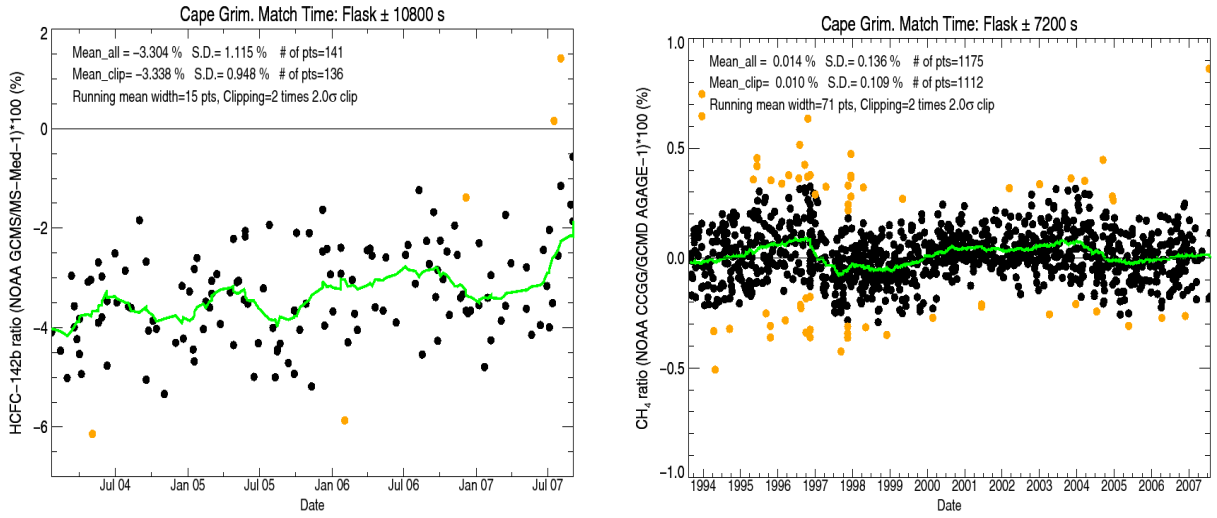

Figure 1. Example of AGAGE *in situ* vs NOAA flask data inter-comparison for HCFC-142b (left) and CH_4 (right) at Cape Grim. The HCFC-142b comparison shows an offset between the two data sets due to different calibration scales (SIO-2005 and NOAA HFC-142b scales) and indicates a small trend with time. The comparison for CH_4 shows excellent agreement between the two data sets and calibration scales (Tohuku University and NOAA-2004 gravimetric CH_4 scales).

Measurements of Light Alkanes (C_2-C_4) in Firn Air at Summit, Greenland and West Antarctic Ice Sheet Divide, Antarctica: Is there Evidence for a Recent Decline in Polar Tropospheric Levels?

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Light alkanes are an important part of the tropospheric photochemical system, acting as precursors for ozone (O_3) and carbon monoxide (CO) and as a removal mechanism for the hydroxyl radical (OH.) In this study, we report measurements of ethane (C_2H_6), propane (C_3H_8), and n-butane (n-C_4H_{10}) in firn air collected at Summit, Greenland (May-June 2006) and West Antarctic Ice Sheet Divide (WAIS-D) (Dec-Jan 2005-2006.) C_2H_6, C_3H_8, and n-C_4H_{10} levels in Summit firn were in the 1.5-2.0 ppb, 400-600 ppt, and 150-250 ppt range, respectively. These levels are within the range of modern mean annual levels in surface air. C_2H_6, C_3H_8, and n-C_4H_{10} mixing ratios measured in the WAIS-D firn were much lower than the Summit values, ranging from 200-300 ppt, 20-40 ppt, and 10-20 ppt, respectively. This is consistent with expectations from the interhemispheric differences in the distribution of sources for these short-lived gases.

The reliability of firn air as an archive for tropospheric levels of light alkanes was assessed by comparison of firn air records to surface air flask measurements. If the firn air alkane data are interpreted as atmospheric histories, the depth profiles suggest that there has been a decline on the order of 25-30% in annual mean levels over Greenland between 1970 and 1990. WAIS-D data suggest steady C_2H_6 levels over the West Antarctic Ice Sheet in 1980s, followed by a 25-30% decline in the 1990's. Trends in C_3H_6 and n-C_4H_{10} data from WAIS-D are harder to interpret due to higher noise in the measurements resulting from lower background levels.

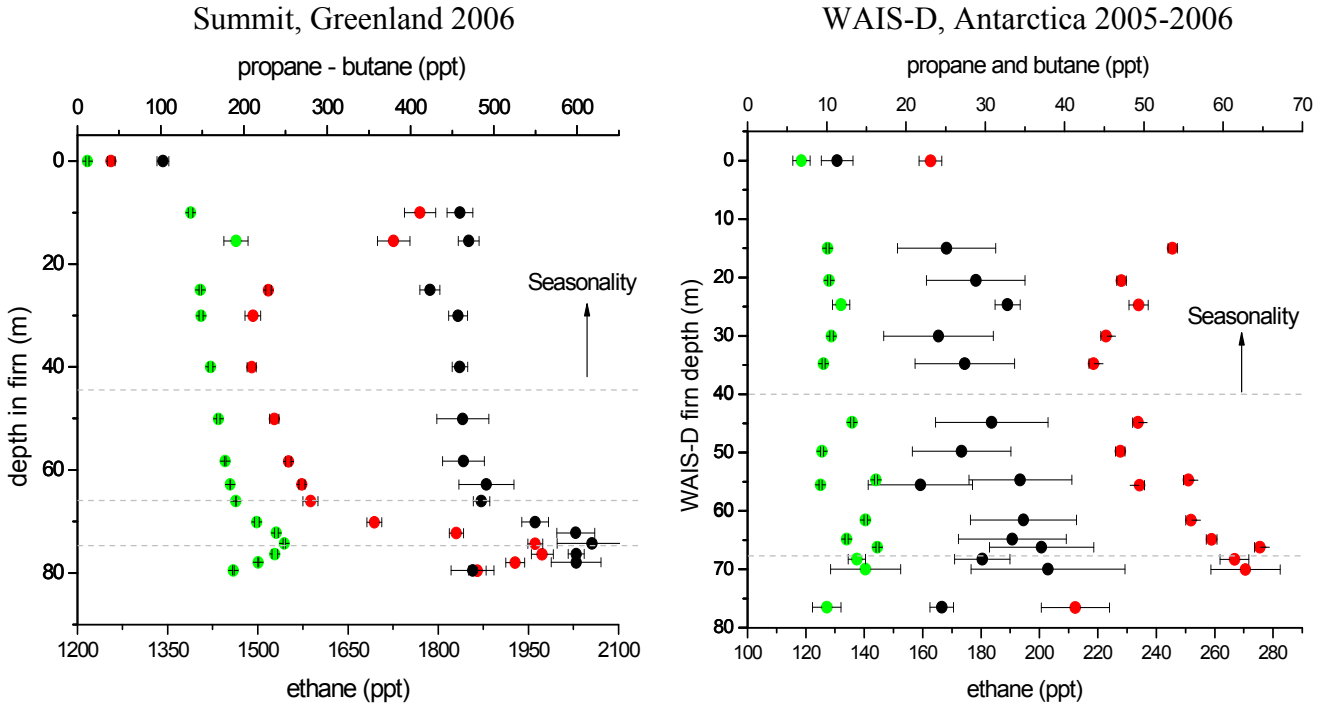

Figure 1. Depth profiles of ethane (red), propane (black), and n-butane (green) measured in firn air from Summit, Greenland (left) and West Antarctic Ice Sheet Divide, Antarctica (right). Light alkanes display strong seasonality in polar latitudes because their primary sink is OH oxidation. Modeling experiments suggest that the effects of this seasonality do not penetrate to depths deeper than 40m.

Identifying and Quantifying Sources of Halogenated Greenhouse Gases Using Lagrangian Dispersion Methods

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Halogenated greenhouse gases are continuously monitored at the atmospheric research station "O. Vittori" located on the top of Monte Cimone, Northern Apennines, Italy (44°11' N, 10°42' E) at the altitude of 2165 m a.s.l., in the frame of the European funded Project SOGE (System for Observation of halogenated Greenhouse gases in Europe, URL http://www.nilu.no/soge). SOGE is an integrated system based on a combination of observations and models. Such an integrated approach allows verifying emissions of halogenated greenhouse gases on a regional scale. Results obtained are useful to ascertain compliance with international protocols regulating production/emission of halogenated greenhouse gases. Beside Mt Cimone, the SOGE network includes the research stations Mace Head (IE), Ny-Ålesund (Spitsbergen, NO), Jungfraujoch (CH) and Monte Cimone (IT), two of which (Jungfraujoch and Monte Cimone) are mountain sites, whose location is crucial in assessing the role of specific potential source regions in Europe.

In this study, in order to identify halocarbons source regions, the following models have been used i) MM5 to reproduce meteorological fields; and ii) FLEXPART to simulate tracers dispersion.
The method here proposed implies initially that concentrations at the receptor site, produced by a homogeneous arbitrary emission field, are simulated. The choice of enhancing factors, converting simulated concentrations into observed ones, could be assimilated to a multiple linear regression problem. Here, for the determination of the best group of regression coefficients, a stepwise regression procedure is proposed.

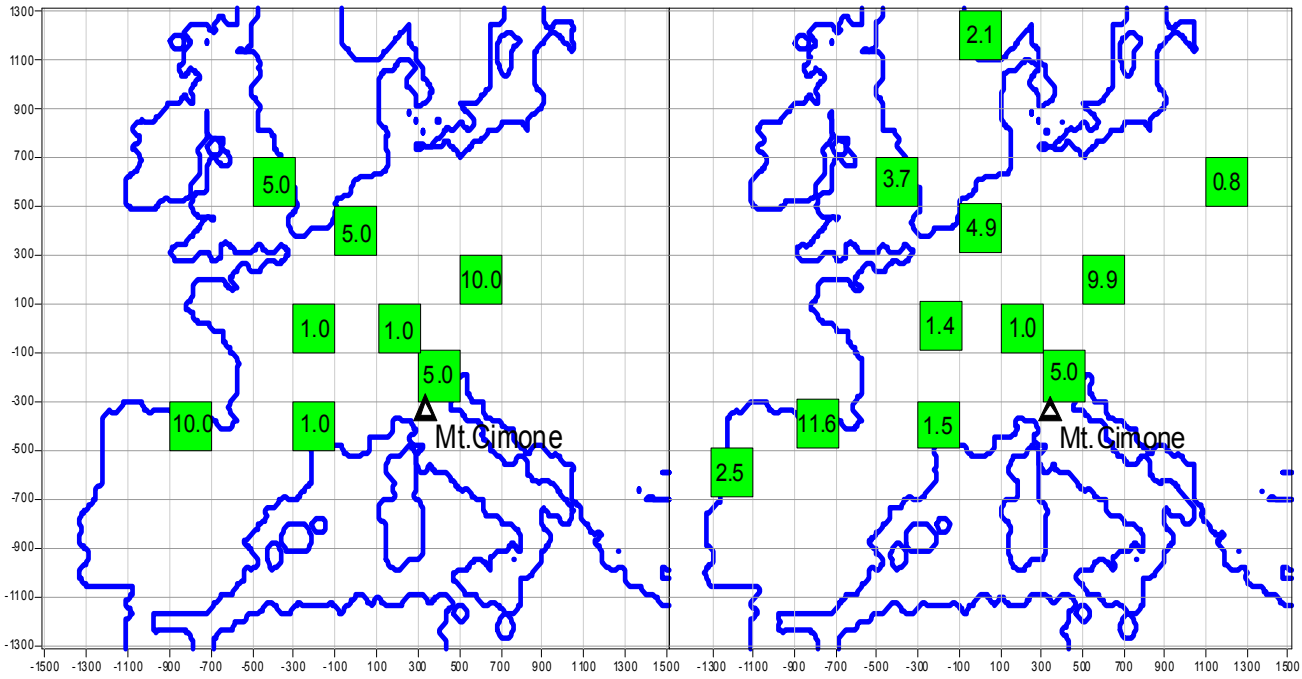

Figure 1. **Left:** Strength of sources used in the synthetic test field. **Right:** Sources' position and strength obtained by the model. Triangle represents the receptor's position (Mt Cimone station).

Stratospheric Air Sampled at the Surface at Mauna Loa Observatory

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In situ trace gas measurements located at the Mauna Loa, Hawaii NOAA baseline observatory (MLO) have detected periodic intrusions of stratospheric air. The Chromatograph for Atmospheric Trace Species (CATS) was installed in 1998 and continues to make hourly air measurements of 14 non-CO_2 greenhouse gases. Continuous surface ozone (O_3) measurements have been made since 1973. Many of the gases sampled, chlorofluorocarbons (CFCs), CCl_4, SF_6 and halon-1211, have little or no tropospheric loss and are only destroyed in the upper atmosphere. Low concentrations of these gases measured at the MLO surface and high concentrations of ozone indicate potential stratospheric intrusions. Comparisons and correlations with lower stratospheric aircraft measurements also indicate the stratospheric nature of these events.

Further investigation using the National Centers for Environmental Prediction (NCEP) potential vorticity calculations also show the stratospheric nature of the air sampled at the surface. Many of these deep stratospheric intrusions are caused by midlatitude cyclones that extend into the North Pacific subtropics; however, some appear to have different origins. This presentation will explore the frequency and mechanisms of these events.

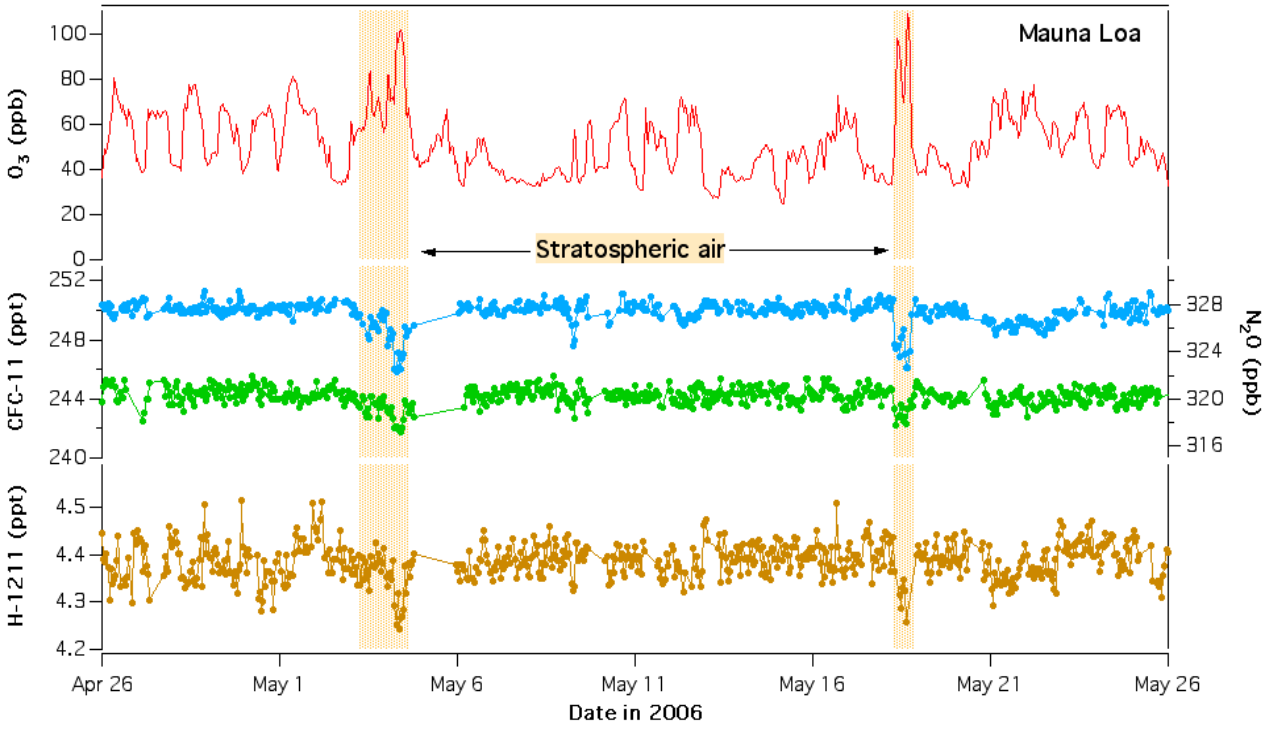

Figure 1. Two stratospheric intrusions measured in May 2006 at the surface of the Mauna Loa observatory. Trace gases that have stratospheric sinks such as CFC-11 (blue), N_2O (green) and halon-1211 (brown) show relatively low concentrations for this latitude. Surface ozone measurements (red) also show high levels typical of stratospheric air.

Primary Study on the Characteristics of Trace Gases in a Clean Area of North China

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From 22 May, 2005 to 30 June, 2006, continuous measurements of O_3, NO_x (NO, NO_2), CO_2, and SO_2, were conducted at the Xinglong station (150 km NE of Beijing) of the Chinese Academy of Sciences atmospheric background observation network. In general, O_3 displayed higher concentration in June and September, and the lowest concentration in December. NO_x concentrations were lowest in August slowly increased through to December. The ratio of NO to NO_x was very low. SO_2 showed the lowest concentrations in July, and then increased gradually. CO_2 exhibited the lowest concentrations in August. During September 10 to November 11 of 2005, solar spectral radiation was also measured at the Xinglong station. UV radiation, an energy source for ozone production and depletion, displayed obvious diurnal and daily variations. Though UV and O_3 have some similar diurnal and daily variations, no good correlation can be found between them during the period of September to November, which shows their relationship is complicated. In more detail, daily maximum hourly averages of UV were generally earlier than those of O_3, which indicates that UV energy is the triggering energy for O_3 formation. In order to better understand O_3 chemistry and photochemistry, solar radiation, O_3 and its precursors of NO_x, VOC_s, and aerosols should be measured simultaneously.

Based on present observations, better air quality occurs in July and August at the Xinglong station. Recent, rapid development of industry, agriculture, and traffic in Beijing City and its surroundings will bring changes in trace gas and aerosol concentrations in these areas. Xinglong station can be considered a good and unique atmospheric background station for the comprehensive study of solar radiation, atmospheric chemistry, and aerosols (especially secondary organic compounds), and how and to what extent human activities influence these parameters. Thus, it is important to carry out long-term monitoring and to study the basic physical, chemical and photochemical processes in the real atmosphere. Meanwhile, reliable and long-term integrated datasets are valuable for input to models and model validation. Collaboration, especially international collaboration, is a good way for us to focus additional resources towards understanding the physical, chemical and photochemical processes in the North China atmosphere, and elsewhere around the world.

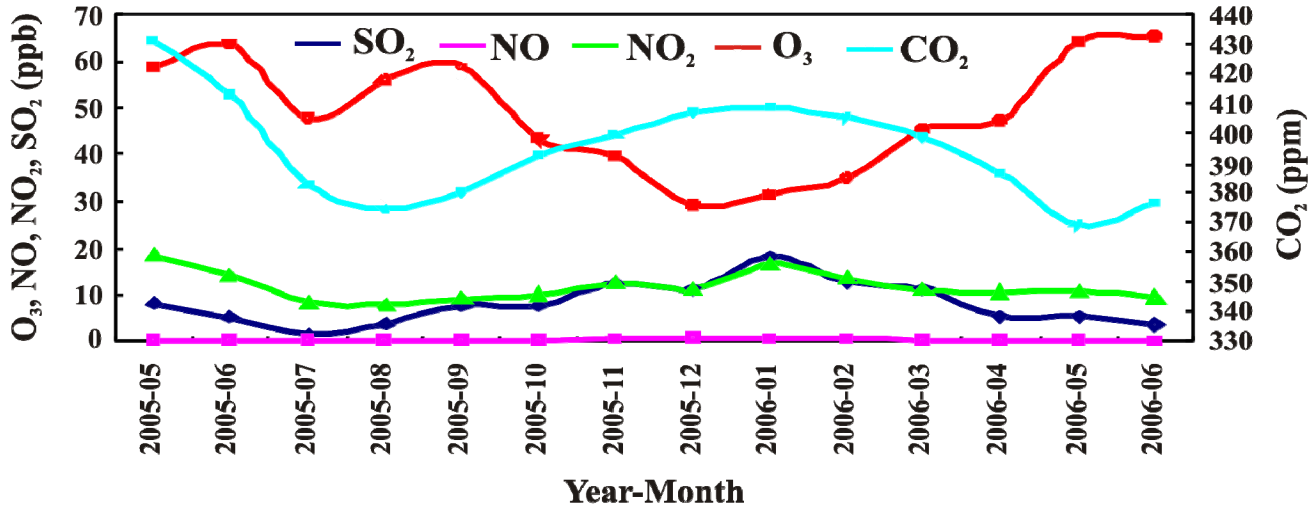

Figure 1. Monthly average concentrations of trace gases at the Xinglong background station 150 km NE of Beijing, China.

Ozone Chemistry and Transport Along a 2000 meter Altitude Gradient in the Colorado Front Range from Twelve Surface Sites and Balloon Sonde Observations

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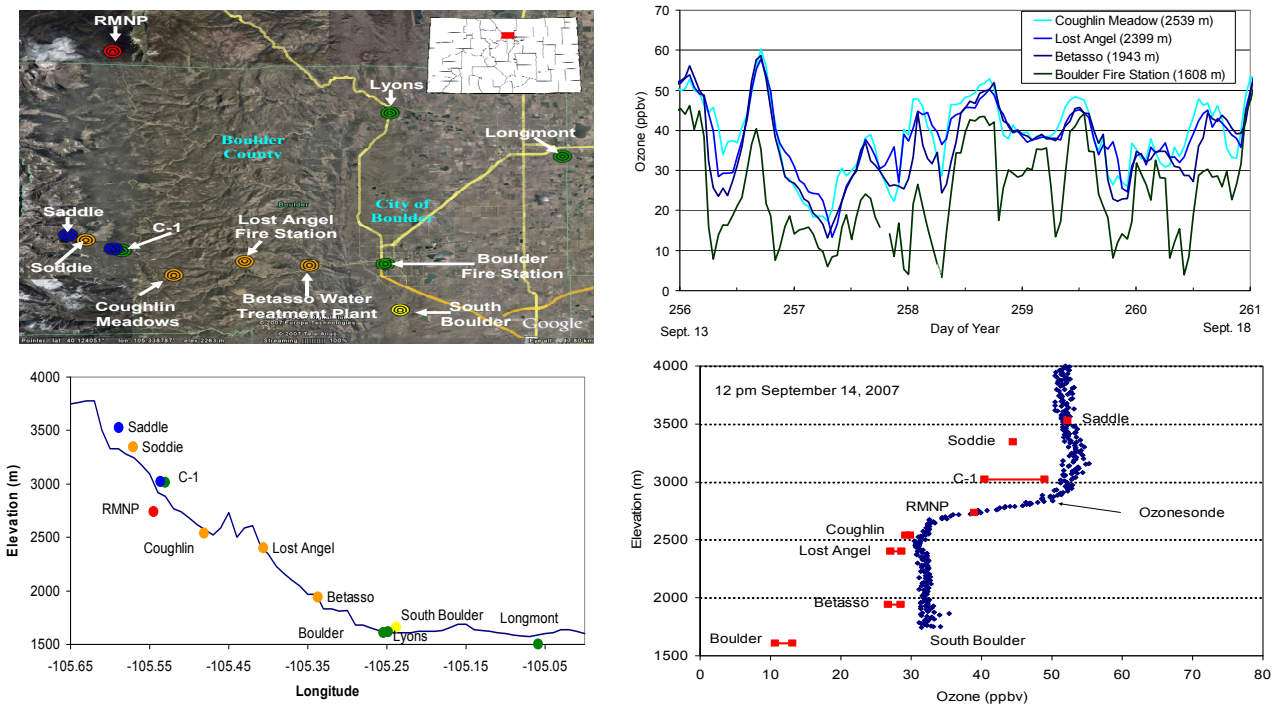
Over the past years summer ozone levels in the Colorado Denver – Front Range Region have repeatedly exceeded the 80 ppbv threshold and in 2007 the region was declared in nonattainment with the 8-hour National Ambient Air Quality Standard. Boulder's elevation of 1600 m above sea level, and its location at the bottom of the eastern edge of the Rocky Mountains and at the periphery of the Denver urban area make it susceptible to both downslope transport of air with elevated ozone originating at higher altitude above the Rocky Mountains, and to polluted air that has experienced anthropogenic ozone production during transport from adjacent urban source regions. During 2007 a number of new ozone surface sites were put on line to create a 12-station surface network in Boulder County. This network is one of the (possibly the) most dense ozone networks. It is also unique in that these stations are spaced at about 200-300 m intervals along a 2000 m elevation gradient. This offers an opportunity to perform new interpretations of the weekly NOAA ESRL ozonesonde launches in South Boulder by comparing same altitude data from the freely rising ozonesondes with the concurrent measurements from surface sites. These analyses have yielded new insights into ozone surface processes. The combined surface and ozonesonde measurements, and the 20+ years record of historical ozonesonde data are furthermore utilized for studying ozone changes, chemistry, and transport in this plains-mountain transition zone.



Figures 1-4. Map and elevation profile (left side, with the insert in the upper right depicting in red Boulder County within the State of Colorado) showing current surface ozone monitoring sites operated by CU-INSTAAR (orange), the State of Colorado (yellow), the National Park Service (red), NOAA (blue), and Boulder County Public Health/CU-INSTAAR (dark green). The example data graphs for September 2007 on the right show the increase in ozone with elevation that is generally seen both in measurements from the surface sites and in the ozonesonde data.

The Short-term and Long-term Stratospheric and Tropospheric Ozone Variability Available from Zenith Sky Measurements.

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This work evaluates the quality of stratospheric and tropospheric ozone information derived from ground-based Dobson and Brewer measurements. It assesses the capability and limitations of Umkehr data, use of Umkehr data for studies of tropospheric ozone variability, and natural and instrument variability in Umkehr data sets. The updated and homogenized SBUV (/2) V8 ozone profile time series is evaluated for internal consistency and potential drifts between different satellites. Long-term records from well-maintained Dobson Umkehr stations are used for assessment of the SBUV (/2) V8 time series collocated with several ground-based stations. The Umkehr ozone data from well-established stations such as Boulder, USA; MLO, USA; OHP, France; Lauder, NZ; and Perth, Australia are selected as reference for the homogenized series of SBUV data for the period 1979-2005. The vertical profile of ozone trends over the northern and southern mid latitudes are estimated from the Umkehr and SBUV (/2) data. The trends are derived using regression to an Effective Equivalent Stratospheric Chlorine (EESC) curve and converted to %/decade using the variation of EESC with time in the 1980s. The long-term ozone trends derived from the two systems are found to be in agreement. A change in the seasonal cycle, ozone trends, and correlations are among several questions addressed in the Umkehr/SBUV data analysis. In addition, the short-term and long-term tropospheric ozone variability derived from two Umkehr data sets available from Boulder, CO, and Mauna Loa Observatory in Hawaii are validated against the reference dataset comprised of co-incident and co-located ozonesonde profiles. Results show that the Umkehr retrieved ozone profile time series are valuable assets in determining ozone inter-annual variability and trends in both stratosphere and troposphere. The Umkehr and SBUV (/2) V8 comparisons indicate drifts between the two systems at some stations (Australia, and possibly at Lauder, NZ). Quality assured Umkehr data show no significant differences in stratospheric ozone trends among stations in the northern mid latitudes. The trend derived from the Lauder Dobson Umkehr data (S.H.) differs from trends derived from the ground-based stations located in the N.H. However, this is most likely related to the difference in the start of the records in the two hemispheres with the Lauder record not beginning until the mid 1980s.

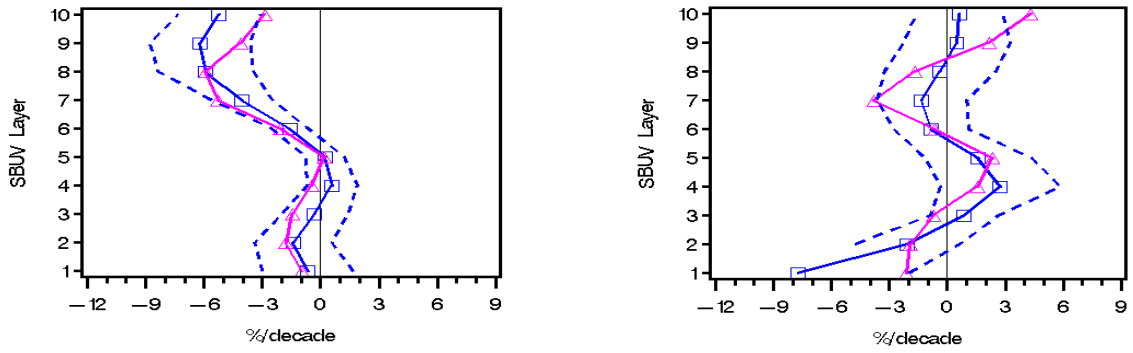

Figure 1. Ozone trends (% per decade) are shown as a function of Umkehr layers. The trends are derived from co-incident, homogenized NOAA/2 SBUV satellite (pink) and Dobson Umkehr (blue) ozone profile measurements for (left) Boulder (1979-2006 time period) and (right) MLO (1982-2006 time period) station records. Dashed lines represent uncertainties of the Umkehr ozone trends regressed against the EESC, QBO and Solar cycle time-series.